CEEW
THE COUNCIL
Centre for Energy Finance

Grid Integration Guarantee

A Financial Buffer to Address Renewable Energy Curtailment

Manu Aggarwal and
Kanika Chawla

Issue Brief | July 2019


Image: Pixabay

Grid Integration Guarantee

A Financial Buffer to Address Renewable Energy Curtailment

MANU AGGARWAL AND KANIKA CHAWLA

Issue Brief
July 2019
ceew.in

Suggested citation: Aggarwal, Manu, and Kanika Chawla. 2019. *Grid Integration Guarantee: A Financial Buffer to Address Renewable Energy Curtailment.* New Delhi: Council on Energy, Environment and Water.

Cover image: iStock.

Publication team: Alina Sen (CEEW), Mihir Shah (CEEW), Surit Das, Aspire Design and Friends Digital.

Acknowledgments: We would like to thank the Good Energies Foundation for their support on this report. We would also like to appreciate the contributions of former and current CEEW colleagues, Priyanka Kachru, Anjali Vishwamohanan, Kapardhi Bhardwaj, Arjun Dutt, and Neeraj Kuldeep, to this work.

The **Council on Energy, Environment and Water** (http://ceew.in/) is one of South Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain—and change—the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. In 2018, CEEW has once again been featured across nine categories in the '2017 Global Go To Think Tank Index Report'. It has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

The **CEEW Centre for Energy Finance (CEF)** is an initiative of the Council on Energy, Environment and Water (CEEW), one of South Asia's leading think tanks. CEF acts as a non-partisan market observer and driver that monitors, develops, tests, and deploys financial solutions to advance the energy transition. It aims to help deepen markets, increase transparency, and attract capital in clean energy sectors in emerging economies. It achieves this by comprehensively tracking, interpreting, and responding to developments in the energy markets while also bridging gaps between governments, industry, and financiers.

Council on Energy, Environment and Water
Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi – 110067, India

CEEW Centre for Energy Finance

The CEEW Centre for Energy Finance (CEF) is an initiative of the Council on Energy, Environment and Water (CEEW), one of South Asia's leading think tanks.

CEF acts as a non-partisan market observer and driver that monitors, develops, tests, and deploys financial solutions to advance the energy transition. It aims to help deepen markets, increase transparency, and attract capital in clean energy sectors in emerging economies. It achieves this by comprehensively tracking, interpreting, and responding to developments in the energy markets while also bridging gaps between governments, industry, and financiers.

The need for enabling an efficient and timely energy transition is growing in emerging economies. In response, CEF focuses on developing fit-for-purpose market-responsive financial products. A robust energy transition requires deep markets, which need continuous monitoring, support, and course correction. By designing financial solutions and providing near-real-time analysis of current and emerging clean energy markets, CEF builds confidence and coherence among key actors, reduces information asymmetry, and bridges the financial gap.

Financing the energy transition in emerging economies

The clean energy transition is gaining momentum across the world with cumulative renewable energy installation crossing 1000 GW in 2018. Several emerging markets see renewable energy markets of significant scale. However, these markets are young and prone to challenges that could inhibit or reverse the recent advances. Emerging economies lack well-functioning markets. That makes investment in clean technologies risky and prevents capital from flowing from where it is in surplus to regions where it is most needed. CEF addresses the urgent need for increasing the flow and affordability of private capital into clean energy markets in emerging economies.

CEF's focus: analysis and solutions

CEF has a twin focus on markets and solutions. CEF's market analysis covers energy transition–related sectors on both the supply side (solar, wind, energy storage) and demand side (electric vehicles, distributed renewable energy applications). It creates open source data sets, salient and timely analysis, and market trend studies.

CEF's solution-focused work will enable the flow of new and more affordable capital into clean energy sectors. These solutions will be designed to address specific market risks that block capital flows. These will include designing, implementation support, and evaluation of policy instruments, insurance products, and incubation funds.

About the authors

Manu Aggarwal

manu.aggarwal@ceew.in

Manu is a climate and energy expert and works on the efficient allocation of risks to minimise resource wastage. His current research interests lie at the intersection of development policy, finance, technology, and institutions. He designs market-transformative insurance products, and restructures commercial contracts to de-risk renewables. In his previous avatars, he worked in business analytics, energy commodities trading, and international development. Manu is a graduate in Mechanical Engineering from Thapar University and is waiting for his CFA charter from the CFA Institute, USA.

"Grid integration is the biggest deterrent to the deep penetration of renewables in India and the wider world. Mitigating the receivables' uncertainty arising out of curtailment is key to bringing in large quantities of institutional capital to the Indian and global renewable energy sector. The Grid Integration Guarantee could be a powerful force in furthering that cause."

Kanika Chawla

kanika.chawla@ceew.in

Kanika Chawla is a policy specialist working at the intersection of renewable energy and financial markets. She is the Director of the CEEW Centre on Energy Finance and also manages the Council's research and outreach in renewable energy policy, regulation, markets, and socio-economic value. She is actively engaged with private and public enterprises within and outside India in designing and developing financial de-risking instruments. Kanika has an MSc in Economics and Development Economics from the University of Nottingham, and an undergraduate honours degree in Economics from Miranda House, University of Delhi.

"The evolution of the energy mix requires the energy system to evolve with it. In the Indian context, the growing share of variable renewables poses a grid integration challenge that is likely to become more severe before it gets better. The Grid Integration Guarantee provides a short- to medium-term financial buffer such that the feasibility of existing projects, as well as those in the pipeline, is not affected by the growing risk of curtailment."

Contents

Part 1 What, where, when, and why of curtailment **3**

1. What is curtailment? 3
2. What is the extent of curtailment? 3
   2.1 Extent of curtailment in international jurisdictions 3
3. Why does curtailment happen? 4
   3.1 Commercial considerations 5
   3.2 Technical considerations 5
4. Is curtailment risk prevalent in India? 6
5. Why is it important to mitigate curtailment risk? 7
6. The political economy of curtailment 7
7. How is the government trying to mitigate curtailment risk? 8
   7.1 Regulatory measures 9
   7.2 Contractual measures 9
   7.3 Technical measures 9

Part 2 Grid integration guarantee (GIG) **10**

1. Context and motivations 10
2. Is it novel? 10
3. Principles 10
4. Design inputs and methodology 12
   4.1 Methodology 12
   4.2 Data 12
5. Grid integration guarantee (GIG): Additional benefits 13
   5.1 Informing the pace of sustainable RE capacity addition 13
   5.2 Calculating a high-frequency, local, and market-based cost of grid integration 13
   5.3 Moving older and expensive RE capacities to a higher and stable equilibrium 13
6. Structuring 13
   6.1 Governance 13
   6.2 Capitalisation 14
   6.3 Features 14
   6.4 Required technology infrastructure 16
7. Drivers for the uptake of GIG 17
   7.1 Making transcos more accountable 17
   7.2 Debate on the feasibility of must run has started 17
   7.3 Implementation of regulatory infrastructure: Forecasting and scheduling regulations 17
8. Barriers to the uptake of GIG 18
   8.1 Political economy of data transparency 18
   8.2 Not enough insurable interest 18
   8.3 Inertia in older PPAs 18
   8.4 National security issues 18
9. Next steps 19
   9.1 Gauging insurable interest 19
   9.2 Model the future grid 19
   9.3 Urging states to make grid dispatch data available 19
10. References 20
11. Annexures 23

List of tables

Table 1	Type of curtailment based on RE tariffs	5
Table 2	De-risking a RE portfolio is cheaper than de-risking standalone projects in risky locations	11
Table 3	A sample case showing calculation of payouts and annual reconciliation	15
Table 4	A sample case showing calculation of payouts with GIG covering penalties	15
Table 5	Range of premium rates for different circles for wind generators	16

List of figures

Figure 1	GIG only covers the curtailment risk	14

Abbreviations

ARIMA	autoregressive integrated moving average
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CEF	Centre for Energy and Finance
CERC	Central Electricity Regulatory Commission
CTU	central transmission utility
DSM	deviation settlement mechanism
DISCOM	distribution company
FIT	feed-in tariff
F&S	forecasting and scheduling
FY	financial year
GIG	grid integration guarantee
GW	gigawatt
IISD	International Institute of Sustainable Development
ISRO	Indian Space Research Organisation
ISTS	Inter State Transmission System
KWh	kilowatt-hour
MNRE	Ministry of New and Renewable Energy
MW	megawatt
NLDC	National Load Dispatch Centre
NPA	non-performing asset
NDC	new distribution capability
NTPC	National Thermal Power Corporation
PGCIL	Power Grid Corporation of India Limited
PPA	power purchase agreement
POSOCO	Power System Operation Corporation
RE	renewable energy
RESD	regional economic and social development
RLDC	regional load dispatch centre
RPO	renewable purchase obligation
SECI	Solar Energy Corporation of India
SERC	state electricity regulatory commission
SLDC	state load dispatch centre
SLU	state transmission utility
TRANSCOs	transmission company
US	United States
UH	utilisation hour

Abstract

The infrastructure, regulation, and policy for the effective integration of renewable energy (RE) is, increasingly, proving to be inadequate in India and the world. It is symptomised by the curtailment or backing down of RE generation. The curtailment of RE generation results in the inefficient utilisation of installed RE capacity and lower than expected returns for developers and investors. The declining viability of projects with the backdown could potentially result in stressed assets for banks and, more importantly, equity investors. But there is no de-risking mechanism. A new and robust technical and regulatory paradigm is needed for the integration of renewables is an urgent, interim solution so that curtailment does not make existing and upcoming projects unviable.

The proposed solution, a grid integration guarantee (GIG), offers cover against tail-end curtailment risk with market-reflective pricing. The use case has been designed for the state of Gujarat, using data for solar and wind generation spanning January 2015 to July 2017. At different sites, the premiums for covering 100 per cent of the tail-end curtailment risk varied between 6 per cent and 29 per cent, indicating that the severity of curtailment risk is localised.

Background

Limiting the extent of anthropogenic climate change is one of the most pressing global challenges today. The decarbonisation of the global growth trajectory is essential to restrict temperature rise to below 2^{o} C, as envisioned by the Paris Climate Agreement. Emissions by all sectors need to fall to achieve the goals of the Paris Agreement, but the decarbonisation of the power generation sector is critical. Electricity and heat production is the largest sectoral contributor to global greenhouse gas emissions, accounting for nearly a quarter of global emissions (Global greenhouse gas emissions data 2019). The decarbonisation of the power sector could bolster emissions reduction efforts through the electrification of the transportation sector, which accounts for around 14 per cent (United States Environmental Protection Agency 2017) of global emissions.

The importance of decarbonising the power sector is reflected in India's commitments under the Paris Agreement, which target an increase in the share of non-fossil fuel-based generation capacity to 40 per cent by 2030 (NDC Registry (interim) 2019). In the shorter term, by 2022, India aims to set up 175 gigawatt (GW) of renewable energy (RE) capacity (Bureau 2017). To ensure an increase in the share of RE in the energy mix, however, capacity addition alone is insufficient; it must be complemented by its integration into the grid such that RE forms a significant part of the energy generation mix.

The infrastructure, regulation, and policy for the effective integration of renewable energy (RE) is inadequate. It is symptomised by the curtailment or backing down of RE generation, where the grid operator issues instructions to limit the output of one or more RE generators. Most RE power purchase agreements (PPAs) in India have a must run clause. The clause requires the system operator not to list RE in the merit order of the dispatch but, irrespective of the cost, to integrate it into the grid, except when the variability of renewables adversely impacts grid safety (which occurs infrequently). As a result, curtailment of RE generation is permitted only for technical reasons such as grid congestion or instability.

However, there is strong evidence that curtailment occurs also for commercial reasons (Rajasthan Electricity Regulatory Commssion 2017), as it is cheaper for distribution companies (discoms) to procure power from thermal generators than from RE generators. The curtailment of RE generation results in the inefficient utilisation of installed RE capacity and lower returns for developers and investors. This hurts investor confidence; and the declining viability of projects, with the backdown, could potentially result in stressed assets for banks.

With the increasing competitiveness of RE tariffs, commercial curtailment is likely to decline significantly. However, two factors other than the final levelised tariff have a significant bearing on curtailment. The primary factor is constituted of technical issues. Growing shares of variable RE in the grid can result in instability. Although RE's share in the generation mix is meagre, large volumes of renewable electricity generated in certain renewable-rich regions can cause instability concerns, and this risk can lead the system operator to issue backdown instructions.

The other determinant is the tariff design. Thermal generators receive a fixed and a variable component of the agreed tariff. The risk posed by backdown is lower, as their fixed tariff is not affected, and the marginal cost of thermal power is only its variable tariff. But RE generators have a single-part tariff, and RE continues to face the risk of technical curtailment despite declining tariffs because the entire tariff could potentially be 'saved' if backdown orders were issued. So, although this type of commercial curtailment violates PPAs, financially over-leveraged utilities have adopted this practice in some instances.

In the absence of adequate measures for addressing these concerns around grid integration, instances of curtailment are likely to increase with rising RE penetration and reduce the attractiveness of the RE sector for investors.

To address the challenge of RE integration, the central and state governments and civil society organisations (CSOs) are considering technical and regulatory interventions such as strengthening the transmission infrastructure, deploying utility-scale storage capacity, and making thermal generation flexible. To address curtailment risk, they are considering technical and contractual structures such as minimum offtake guarantee provisions and specific contractual provisions in PPAs (Viswamohanan, Curtailing renewable energy curtailment 2018). Such interventions could reduce the extent of curtailment, but these continue to be expensive in the short term and face resistance from industry participants in some cases. The integration of renewables needs a new and robust technical and regulatory paradigm and also an urgent stop gap solution such that existing and upcoming projects do not become unviable as a result of curtailment.

India will be doubling its RE capacity in the coming three years to realise its 2022 targets. To do so, it needs to address the risk posed by the integration of variable RE into the grid. This is especially critical to attract private capital at affordable prices and keep industry enthusiasm up. A technical solution, such as transmission upgrades and dedicated green corridors, is essential for addressing the problem in a holistic manner, but it has a long gestation period. As an interim solution, a synthetic risk buffer would avoid stranded projects, non-performing assets (NPA) stress for banks, and loss of confidence for foreign investors.

The CEEW Centre for Energy Finance proposes a Grid Integration Guarantee (GIG) that will cover against tail-end curtailment risk with market-reflective pricing. This report presents the design, feasibility, and applications of the proposed GIG.

The first part of this report comprehensively describes the challenge of curtailment. Beginning with a definition of curtailment, the report goes on to discuss the prevalence and extent of curtailment in the Indian context. It also briefly summarises the extent of curtailment and the measures adopted for risk mitigation in major international RE markets. The report delves into the reasons for curtailment of RE generation in India, including the political economy of curtailment. It outlines why it is important to mitigate curtailment risk, the measures taken or proposed by the government to address the challenge of curtailment, and the need for additional interventions to address curtailment risk.

The second part of the report delves into the details of how curtailment risk can be mitigated, focussing on the GIG. **The report outlines the principles and the motivation for the development of the GIG, before providing details on the methodology adopted for designing the instrument. It delves into various aspects of the GIG, including risk coverage, governance, capitalisation, and product features.** The report next highlights the drivers that would support the successful deployment of the GIG and the barriers to its uptake. It concludes by outlining the future steps in the development of the GIG if it were to be operationalised.

Part 1 What, where, when, and why of curtailment

1. What is curtailment?

'Curtailment' in this report refers specifically to the curtailment of RE generation, or the forced reduction in the output of a generator from what it could otherwise produce given available resources (e.g., wind or sunlight (Lori Bird n.d.)). Curtailment occurs when a transmission system operator issues an instruction to limit the energy output of a specific or a group of RE generators. As per the Indian Electricity Grid Code and most RE PPAs, compensation for the curtailment of solar and wind generation excludes any such instruction given for a technical reason to ensure grid security and safe operations (Central Electricity Regulatory Commission 2010).

Solar and wind energy generators are characterised by the variability and intermittency of output with changing seasons, weather conditions, and even time of day, due primarily to diurnal and seasonal variations in resource availability (Mulder 2014). Variations in solar and wind energy generation could necessitate the curtailment of these sources of generation. The extent of curtailment depends upon the adequacy of grid integration measures for RE installed capacity. Therefore, it varies by jurisdiction. Where grid integration measures are inadequate, the incidence of curtailment is expected to be higher.

2. What is the extent of curtailment?

There is anecdotal evidence for the incidence of curtailment across states in India, but there are no definite numbers with regard to its extent across the country. Curtailment is heavily influenced by local factors, such as the status of the grid infrastructure near the RE generation site and resource variability at those sites. There is considerable variation in the quantum of curtailment across months, states, and even districts in a state. The estimation of the extent of curtailment requires the availability of granular data on generation and the status of grid infrastructure at the substation level, which is usually not available in the public domain.

> There is considerable variation in the quantum of curtailment across months, states, and even districts in a state. The estimation of the extent of curtailment requires the availability of granular data on generation and the status of grid infrastructure at the substation level, which is usually not available in the public domain.

Petitions by the industry to regulators and media reports provide some indication of the extent of the problem. The problem of RE curtailment is reported to be rampant in Tamil Nadu (Pradhan 2016). In comments to a regulator, an industry body asserted that Tamil Nadu has experienced wind energy curtailment to the extent of 50 per cent.[1] Industry petitions have also brought the issue of curtailment of solar generation to light in Tamil Nadu. The tariffs of existing installed solar capacity are higher than that of conventional sources; the petitions cite this difference as a possible reason for the backdown of solar generation (Smiti 2017).

The issue of curtailment has been reported as a major problem in Rajasthan, too. In FY 2017, wind energy curtailment in Rajasthan reached 45 per cent, compared to generation at the P90 level of the plant load factor (Business Standard 2017). There is not much information available in the public domain on the extent of curtailment in other states. Based on data pertaining to the scheduling of RE generation sourced from the website of the Gujarat state load dispatch centre (SLDC), CEEW CEF has estimated RE curtailment rates for Gujarat and used that as the basis of analysis for the GIG (Annexure 1).

2.1 Extent of curtailment in international jurisdictions

The problem of curtailment has been observed in several international jurisdictions.

China

Curtailment in China, the world's largest RE market, has been ascribed to the inadequacy of grid infrastructure, limited interprovincial transfer of electricity, and overcapacity in RE generation (Asian Power 2016). In the first three quarters of 2017, the country had an RE curtailment rate of 12–13 per cent (Deign 2017). In 2016,

1 ibid

the curtailment rate was around 10 per cent for solar energy and 17 per cent for wind energy.[2]

To mitigate the problem, China adopted a policy of minimum offtake of solar and wind generation. Applicable to select cities in eight provinces and three autonomous regions, the policy mandates minimum RE offtake quotas on grid operators in the form of minimum annual utilisation hours (UH) of RE generation. The UHs are different for region and vary between 1,300–1,500 hours for solar and between 1,800–2,000 hours for wind generation (Asian Power 2016). As an additional measure to ensure compliance, regions that fail to meet their UHs are not permitted to start the construction of new solar or wind projects. The minimum offtake provisions function as a curtailment guarantee, but there is no provision for compensation for RE generators in the case of non-compliance by grid operators.[3] Such provisions were contemplated by policymakers, but they were not operationalised.

Germany

The problem of curtailment has also been observed in Germany, the world's third largest producer of wind energy and fourth largest producer of solar energy (IRENA 2018).

Wind energy curtailment rates stood at 4–5 per cent in 2016 (Michael Joos 2018). In the case of curtailment, RE generators are compensated at the rate of 95 per cent of their forgone revenues.[4] The compensation for the year 2014 amounted to USD 94 million, which represented the curtailment of around 1.2 per cent of RE capacity under the feed-in-tariff (FIT) regime (John 2016). The country is investing in strengthening transmission infrastructure to facilitate the integration of a greater share of RE generation.[5]

United States

The problem of curtailment has also been reported in the US. The regional variation in curtailment rates is considerable, but curtailment rates of wind energy generators were below 4 per cent for all regions in 2013 (Lori Bird n.d.). Compensation for RE curtailment is provided by some transmission system operators. However, transmission system operators offer compensation under specific conditions; these, and the rates at which generators are compensated, vary considerably.

3. Why does curtailment happen?

Solar and wind energy generation plants have been accorded must run status (Box) under the Indian Electricity Grid Code Regulations, 2010 (later adopted into state electricity grid codes). That implies an exemption from merit order dispatch principles (Central Electricity Regulatory Commission 2010). But the transmission system operator may instruct the solar or wind generator to back down generation for grid security or the safety of equipment or personnel.[6] However, there is strong evidence from market intelligence, media reports, and industry feedback that the decision to back down RE generation is driven by commercial considerations (MNRE 2016): state discoms find it cheaper to source electricity from thermal generation than RE generation.

Box 1: Must run status for solar and wind generation

The merit order despatch principles require the cheapest power to be made available to consumers first and more expensive power to be supplied only if cheaper power is not available or inadequate. The exemption from merit order dispatch principles was granted to solar and wind generation because tariffs corresponding to these sources were considerably higher than those for conventional sources till a few years ago and deterred offtakers from scheduling renewable power for generation.

The must run status provided greater certainty for the offtake of RE generation and thereby helped attract more investment into the sector. However, with an increase in the share of variable RE generation in the grid, the must run status is becoming untenable. Because the prevailing measures for grid integration are inadequate, the transmission infrastructure has a limited ability to accommodate the rising share of variable RE generation. The competitiveness of RE tariffs makes the must run clause much easier to comply with commercially, even as the technical constraints grow.

2 ibid
3 ibid
4 ibid
5 ibid
6 ibid

3.1 Commercial considerations

Commercial considerations for curtailment include different tariff structures of thermal and renewable energy generators, and relatively higher tariffs of installed renewable energy capacity in the past.

One-part tariff structure for RE

In India, the tariff structure of conventional generation is different from that of RE generation. Conventional sources of generation, such as thermal and hydro, are characterised by a two-part tariff structure consisting of a fixed and variable component. The fixed component is independent of the electricity supplied by conventional generators; the variable component is linked to the actual electricity supplied. The variable component of the tariffs is meant to compensate thermal generation for variable costs, which are primarily fuel-related expenses. In contrast, RE generation is characterised by a one-part tariff. This kind of tariff structure reflects the cost structure of RE generation, which primarily requires upfront investment and has minimal recurring operational costs and no fuel-related expenses.

Higher tariffs for older RE generation capacity

Older RE capacity (projects awarded around two years ago) is characterised by tariffs significantly higher than those pertaining to conventional generation (table 1). The relative attractiveness of conventional power tariffs versus installed older RE capacity constitutes a perverse incentive for state utilities to curtail RE generation. Table 1 summarises the predominant type of curtailment based on the magnitude of RE tariffs.

3.2 Technical considerations

Technical drivers of curtailment of renewable energy generators are unplanned maintenance and orders of curtailment issued by state/regional/national load dispatch centres on account of imbalances in the grid.

Grid unavailability

The operations of transmission licensees are subject to minimum performance standards pertaining to transmission system availability as prescribed by the

Table 1: Type of curtailment based on renewable energy (RE) tariffs

	Newly awarded capacity (tariff < INR 3/kWh)	Intermediate RE capacity (INR 3/kWh <tariff < INR 5/kWh)	Old RE capacity (tariff > INR 5/kWh)
Type of curtailment	Predominantly technical	Technical and some commercial	Both technical and commercial

Note: The classification of the type of curtailment is based on a comparison of RE tariffs with the average of the variable portion of thermal tariffs for FY 2017 in five RE-rich states (Madhya Pradesh, Andhra Pradesh, Rajasthan, Maharashtra, and Gujarat) which stands at INR 3/kWh.

Source for data on thermal tariffs: Josey et al., The Price of Plenty, 2017

A consequence is that state discoms have to pay the fixed component of conventional power tariffs in case these sources are curtailed but not for RE sources. This constitutes a perverse incentive for state transmission utilities (STUs) to back down RE generation instead of conventional generation. While tariffs corresponding to newly tendered RE capacity are cheaper than thermal tariffs, RE tariffs still exceed the variable components of thermal tariffs. Thus, even newly tendered RE capacity is prone to curtailment on commercial considerations, though less so than older RE capacity as a result of the relative magnitudes of the tariffs corresponding to each kind of capacity (table 1). For curtailment on commercial considerations to be eliminated, RE tariffs would need to decline below the variable component of thermal tariffs (table 1).

Central Electricity Regulatory Commission (CERC) or the state electricity regulatory commissions (SERCs) (CERC 2017). The adherence to these performance

> If the transmission licensee is unable to conform to the minimum standards of grid availability, affected parties are eligible to claim compensation from the transmission licensee after making an application to the CERC or the respective SERC. However, compensation is limited to the transmission charges of the particular element of the system to the extent to which it has affected the supply of electricity.

standards is to be ensured on a monthly basis. Most outages of the transmission system are scheduled for maintenance, but there are instances of unscheduled maintenance, leading to unplanned outages too. During these unplanned outages, power that is scheduled will be curtailed.

If the transmission licensee is unable to conform to the minimum standards of grid availability, affected parties are eligible to claim compensation from the transmission licensee after making an application to the CERC or the respective SERC. However, compensation is limited to the transmission charges of the particular element of the system to the extent to which it has affected the supply of electricity (Central Electricity Regulatory Commission 2012). Thus, there is no recourse for generators to claim compensation for the loss of revenue as a result of the curtailment of generation resulting from grid unavailability below minimum performance standards. Moreover, since solar and wind generators are exempt from inter-state transmission charges – the current waiver is valid for projects commissioned till March 2022 – only discoms are eligible for claiming compensation pertaining to inter-state transmission (CERC 2018).

Grid management issues

Under Indian electricity regulations, SLDCs and regional load dispatch centres (RLDCs) are the apex bodies for ensuring the integrated operation of the power system in their respective state or region (Central Electricity Regulatory Commission 2010). These responsibilities include the exercise of supervision and control over the grid to ensure the stability of grid operations.[7] Unexpected variations in RE generation or demand-side fluctuations, coupled with technical constraints on the operations of thermal power plants, could necessitate the backing down of RE generation to maintain grid stability.

The CERC regulations prescribe, for greater flexibility in power generation, that central or inter-state power plants should be capable of operating at 55 per cent of installed capacity (Central Electricity Regulatory Commission 2016). However, older coal-based plants are unable to meet this requirement; these can reduce operations only till 70 per cent without oil support.[8] The lack of flexibility in the operation of thermal power plants often necessitates the backing down of RE sources in cases of unexpected variations in RE generation or electricity demand to avoid grid congestion or to maintain the stability of parameters such as grid frequency.

7 ibid

8 Minutes from the meeting of the Renewable Energy Sources Development Committee of the Central Electricity Authority (CEA)

4. Is curtailment risk prevalent in India?

There is some anecdotal evidence of the growing severity of curtailment risk, but there is limited data on the actual size of the risk. Developers do not build in full buffers for such risks in increasingly competitive RE bids, but market participants expect at least some of this curtailment, given the historical instances of curtailment and the state of existing measures for RE integration in various states. Developers and financiers could be factoring some curtailment into their estimates of project cash flows in some cases, depending on the offtaker.[9] The developer forgoes revenue whether an instance of curtailment is anticipated or unanticipated, but unanticipated curtailment is the source of risk, as it has not been factored into the business plan and adversely impacts project viability.

The issue of curtailment risk has not received much prominence in the discourse around the RE sector in India, but the problem is significant, as evidenced by petitions filed by RE developers before SERCs around the issue of unanticipated curtailment in the states of Tamil Nadu (TNERC 2017) (TNERC 2015), Rajasthan (RERC 2017), and Gujarat (GERC 2016). Representations made by developers to the Ministry of New and Renewable Energy (MNRE) constitute further evidence (MNRE 2016). Market consultations, too, suggest that the problem is severe and needs urgent redressal.

5. Why is it important to mitigate curtailment risk?

For the RE sector as well as the broader economy, unanticipated curtailment leads to the inefficient utilisation of RE capacity and resource potential. It adversely impacts the economic viability of projects and potentially stresses assets or NPAs for lenders. Recurring instances of curtailment pose reputational risks for state power sector entities such as SLDCs and discoms. These factors could reduce the attractiveness of the RE sector for investors and affect the pace of RE capacity addition.

9 From discussions with select stakeholders

The mitigation of curtailment risk lowers the cost of capital, ensures that RE tariffs are sustainable, and reapportions risks in the power system more robustly, thus helping to ensure that RE capacity addition continues apace in a sustainable manner.

5.1 Lowering cost of capital

Unanticipated curtailment of generation results in a loss of revenue for RE projects and adversely impacts their viability. Therefore, heightened curtailment risk raises the overall risks associated with RE projects and, in turn, their cost of capital. The mitigation of curtailment risk could help lower the associated risk premiums and, in turn, the overall cost of capital for RE developers. Since the cost of capital accounts for 60–70 per cent of RE tariffs (Chawla 2016), lowering the cost of capital would lower tariffs and, therefore, the burden on consumers.

5.2 Ensuring the sustainability of RE tariffs

The competitiveness of utility-scale RE tariffs has improved considerably over the past few years. Tariffs discovered through the auction route were record-low for solar in 2017 and for wind in 2018. Lowering sectoral risk, and supportive policy developments, played a major role in tariff reduction. In addition, competitive bidding through the reverse auction route has facilitated the lowering of tariffs.

Bidding is competitive; in most cases, RE developers are unlikely to factor in buffers for unanticipated curtailment in their bids for tenders.[10] However, heightened risks of curtailment would negatively impact the viability of these bids and the continued sustainability of the low tariffs seen since 2017 . Mitigating curtailment risk could help ensure the sustainability of RE tariffs. Mitigating risk would also lower the cost of capital, which would, again, contribute to making tariffs sustainable.

5.3 A more robust reapportionment of risks in the power system

Curtailment occurs because RE integration measures are inadequate. Since either central or state government agencies are responsible for ensuring the smooth integration of RE generation capacity, government agencies are primarily responsible for the curtailment risk faced by developers, but developers bear the entire cost of curtailment in terms of forgone revenue. Government agencies should bear the costs of the inadequacy of grid integration measures, or mitigate the curtailment risk for developers. State entities such as RLDCs/SLDCs are in the best position to manage the risk as they are the apex bodies in the integrated operations of the power system, including the scheduling and dispatch of power.

The curtailment risk can be lowered through contractual provisions in PPAs such as minimum offtake guarantees and monetary compensation in cases of non-compliance (Viswamohanan, Curtailing renewable energy curtailment 2018). There is no insurance product for curtailment risk, but it could be managed by one if state entities fully or partially fund insurance premiums for developers. The reallocation of curtailment risks through any mechanism would reduce the uncertainty for RE developers and financiers, thereby translating into lower tariffs and greater offtake by discoms and, eventually, end consumers.

6. The political economy of curtailment

An overwhelming majority of the RE projects in India are set up by private sector developers. Power generated by RE projects is usually sold through long-term PPAs with discoms; a small fraction is sold via the open access route. By the Constitution of India, power distribution is a state subject (Ministry of Power 2019). The vast majority of discoms are state government entities, though some private sector entities also operate in this space, mainly in tier 1 cities.

The transmission utility is the intermediary that owns and operates the transmission network. The intra-state transmission network is set up and operated by state transmission utilities. Power Grid Corporation of India Limited, the central transmission utility, is responsible for setting up and operating the inter-state transmission infrastructure. Some private entities also operate in the transmission sector.

Transmission system operators – SLDCs and RLDCs – match the quantum of electricity injected into the grid with its withdrawal. These entities can issue instructions for the curtailment of generation for technical considerations. Data is not easily available on the state of the grid infrastructure at the substation

10 From discussions with select stakeholders

level; therefore, it is difficult to ascertain whether the instructions from SLDCs for the backdown of RE generation are based on technical considerations or impose checks and balances on SLDCs with respect to curtailment. In past cases alleging curtailment on the basis of commercial considerations, SERCs have deferred to the judgment of SLDCs on whether curtailment occurred based on technical considerations (TNERC 2015). The SLDC is a usually an integral part of the state transmission utility, whereas RLDCs are operated by POSOCO, a central power systems utility. The National Load Dispatch Centre (NLDC) is the apex body that ensures the integrated operation of the national power system.

6.1 RE developers and investors

Instances of curtailment reduce the RE sector's attractiveness for developers and investors. Project developers and financiers must factor in instances of curtailment in their projections of project cash flows. If they do not, unanticipated instances of curtailment would lower returns on investment and affect project viability, and make the terms of finance more stringent for projects in regions where curtailment risk is high.

6.2 State power sector entities

Discoms

Discoms sign PPAs with RE generators to meet their renewable purchase obligations; in the case of newly tendered RE capacity, it also helps to reduce their average power purchase cost (The Economic Times 2018). State discoms have poor finances (Press Information Bureau 2015), and they prefer to offtake power from cheaper sources. State utilities prefer to curtail RE generation rather than thermal generation because tariffs of older installed RE capacity are higher than for thermal power and thermal tariffs are lower than RE tariffs.

State transmission utilities (STUs)

State transmission utilities (STUs) are expected to maintain minimum standards of performance with respect to transmission system availability. In cases of non-compliance with the minimum standards of performance, STUs are expected to compensate affected parties (discoms). The compensation is to be limited to the transmission charges of the particular element of the system to the extent to which it has affected the supply of electricity.

SLDCs

The SLDCs control the scheduling and dispatch of electricity within a state. The state government controls SLDCs, STUs, and state-owned discoms; therefore, their interests are aligned, and SLDCs have an incentive to act in the state discoms' interests in backing down older RE installed capacity instead of thermal generation. Also, SLDCs have the incentive to camouflage non-compliance with minimum performance standards by STUs as reasons for backing down RE sources.

6.3 Central government entities

Being entities under the control of the central government, there is little alignment between the interests of the central transmission utility (CTU) and RLDCs with state utilities. The RLDC is concerned primarily with maintaining grid stability at the regional level and the deviation settlement mechanism (DSM) at state boundaries. The NLDC exercises supervision over RLDCs. Thus, RLDCs and the NLDC do not have any incentive to curtail generation based on commercial considerations.

7. How is the government trying to mitigate curtailment risk?

The central and state governments recognise the need to take additional grid integration measures to complement the setting up of RE generation capacity. Several regulatory, contractual, and technical measures to address the challenge of RE integration are under implementation or consideration.

7.1 Regulatory measures

All the leading states in RE have notified forecasting and scheduling regulations for wind and solar generation in the past 18 months (Part II, Section 7.3), but industry views these regulations as violative of the must run status given to solar and wind generation (Viswamohanan, Curtailing renewable energy curtailment 2018) and has resisted their implementation in some cases (KERC 2016) (RERC 2017).

7.2 Contractual measures

Contractual provisions in the form of minimum offtake guarantee clauses have been considered in PPAs (Rewa ultra mega solar limited 2017). These clauses aim to safeguard the interest of developers and investors in the event of generation curtailment.

7.3 Technical measures

Physical infrastructure

Technical interventions such as the strengthening of transmission capacity, flexible thermal generation, and utility-scale storage are at various stages of consideration or implementation. The ongoing Green Energy Corridor project was envisioned as a dedicated transmission network for RE. It aims to bolster intra-state and inter-state transmission infrastructure and facilitate the evacuation of power generated in RE resource–rich states to load centres located across the country. Utility-scale storage tenders have been floated, and a few pilot projects for flexible thermal are at varying stages of implementation, but the implementation of these interventions has not occurred as planned. Projects aimed at strengthening intra-state and inter-state transmission infrastructure have been delayed (Mondal 2017), utility-scale storage tenders have been cancelled repeatedly (Sraisth 2017), and the deployment of flexible thermal generation (Central Electricity Regulatory Commission 2017) is in the nascent stage.

Digital measures

Efforts are under way to increase the availability of real-time operational data on RE sources. The disparity is considerable in the current coverage of telemetry on RE sources at the SLDC level. Whereas some states such as Karnataka (100 per cent) and Andhra Pradesh (solar 96 per cent, wind 95.5 per cent) have high coverage of RE generation, others such Maharashtra (56 per cent) and Rajasthan (60 per cent for solar and 14 per cent for wind) have lower coverage.[11] Efforts are under way to achieve 100 per cent availability of real time operational data at the SLDC, RLDC, and NLDC level.

If these measures are implemented fully, the extent of curtailment could be reduced to a large extent. But these measures constitute long-term, structural solutions to the challenge of RE integration; in the short term, these measures are expensive. Some have faced delays in implementation and others resistance from industry. Thus, short- to medium-term stopgap solutions are needed to mitigate curtailment risk.

11 Minutes from the meeting of the Renewable Energy Sources Development Committee

Part 2 Grid Integration Guarantee (GIG)

1. Context and motivations

The CEEW CEF has designed the GIG as an interim solution to the growing risk posed by the constraints on integration of variable renewables into the grid.

The GIG (instrument) is built on the intersection of two major disciplines and technologies – big data techniques and actuarial science. Its foundational structure has many data limitations and assumptions to derive proxies, but its logic is robust. The GIG would need to be improved considerably before operationalisation, but if such an instrument were successfully operationalised, the benefits would outweigh the drawbacks. This report presents a first use case and framework to socialise the idea as a potential transformative solution for the Indian RE market (Fankhauser 2015).

> The GIG is built on the intersection of two major disciplines and technologies – big data techniques and actuarial science. Its foundational structure has many data limitations and assumptions to derive proxies, but its logic is robust.

2. Is it novel?

Governments across the world have tried to address the issue of curtailment through executive diktats, regulatory interventions, and improved contracting through balanced PPAs. In India, most PPAs do not address curtailment risk (Viswamohanan, Curtailing renewable energy curtailment 2018). Even the newer PPAs (with the exception of a few, recently signed PPAs) do not address tail-end curtailment risk, thus making the case for an instrument like the GIG.

> Even the newer PPAs (with the exception of a few, recently signed PPAs) do not address tail-end curtailment risk, thus making the case for an instrument like the grid integration guarantee.

Curtailment is a local phenomenon, but it results in a wide distribution of incidence rates even among small geographies. Also, as observed in India (and other countries), administrative boundaries and jurisdictional boundaries of transmission utilities (transcos) are not identical. This leads to friction in implementing even the most well-intended executive and regulatory interventions.

The GIG intends to solve the issues of

- prescription (or non-prescription) of a universal solution for a local issue such as curtailment,
- the mismatch in the jurisdictional areas of administrative governments and local transcos,
- increased technical curtailment risk with the share of RE on the rise, and
- tail-end curtailment risk.

The GIG intends to do this by offering an instrument with market-reflective prices based on data on integration at the substation level and cover for the tail-end curtailment risk.

> Since a transco is solely responsible for the state of the electricity grid, it is best suited to bear the bulk of the curtailment risk borne out of lack of transmission availability for renewables integration.

3. Principles

3.1 Efficient allocation of risks

The GIG needs to be priced attractively for RE investors and developers to adopt it. It should lead to a secular decline in the structural risk of curtailment in the medium to long term. Since a transco is solely responsible for the state of the electricity grid, it is best suited to bear the bulk of the curtailment risk borne out of lack of transmission availability for renewables integration. The transcos and SLDCs could further allocate some of the risks to other parties such as discoms. The existing market design does not include any incentives for transcos or load dispatch centres to not curtail RE generation. However, a re-appropriation of risks among the various entities could create the conditions and incentives necessary for transcos to build and upgrade infrastructure on time and for SLDCs and discoms to effectively plan dispatch using the forecast provided by generators.

3.2 Dynamic

The GIG is conceptualised to be as dynamic as possible in determining the risk premium. Designed to leverage the highly sophisticated information systems used in the power dispatch and the debt repayment cycles to schedule payouts of claims, the GIG will need to be nimble. Given the evolving regulatory environment, forecasting regulation, DSM, and the final schedule submitted by generators, the generation data reported by SLDCs/RLDCs at 15-minute levels will form the cornerstone of the pricing structure.

3.3 Sunset clause

The GIG is envisaged as a stopgap, short- to medium-term measure, till the required structural reforms are implemented. To meet Indian RE ambitions and have a vibrant market, market participants such as RE investors and developers need to be comfortable with the level of curtailment risk before the GIG is withdrawn from the market. The value addition of a risk-specific intervention is that it helps create investor confidence in the market, such that once the curtailment levels are low, investors who invested with the GIG would be comfortable to lend directly to projects. Blanket credit enhancements do little to raise market confidence.

3.4 Participation of the private sector

This instrument would work well in collaboration with suitable private sector actors such as reinsurance and insurance companies, and financial risk managers. However, the modalities of collaboration would depend on the operational design and the size of the initial pilot (Section 6.1). The GIG is designed to address a specific risk (Curtailment risk) that impedes the flow of certain categories of capital, at affordable prices, into RE projects in India. The pace and price of the growth of the Indian RE market depends largely on the sector's ability to raise debt and equity at lower prices. The GIG would enable this as it addresses a major risk variable (Curtailment risk) at a market-reflective price that is shared by multiple parties within the ecosystem.

3.5 De-risking both standalone projects and portfolio of projects

The success of this instrument would depend on the insurable interest. Interest from actors such as RE developers and debt and equity investors will drive its success. Equity investors, but not lenders, perceive curtailment risk as a major risk (Chawla 2016), but debt investors too are becoming increasingly cognisant of this risk. The lenders' perception of risk could be due to the lower levels of curtailment in existing projects, which in turn might be arising from the lower penetration of renewables into the grid so far. The resulting perception could also be due to the mutualisation benefit arising out of cross-subsidisation between multiple projects at the portfolio level. As the penetration of renewables along with the curtailment risk increases in the overall energy mix, this perception of lenders towards renewables could change.

Equity investors, but not lenders, perceive curtailment risk as a major risk but debt investors too are becoming increasingly cognisant of this risk.

Mutualisation benefit for intra-state and inter-state projects

States where curtailment could be high in certain months could be mutualised by lower curtailment in other states. A RE developer/investor with projects in multiple states/countries could enjoy lower premiums on its portfolio compared to a developer with projects only in handful of states. But the instrument even offers de-risking for small developers having only a handful of projects concentrated in one circle/state, albeit at a higher price (Table 2).

Table 2: De-risking a RE portfolio is cheaper than de-risking standalone projects in risky locations

No.	Portfolio/standalone project	Amreli (in MW)	Anjar (in MW)	Junagadh (in MW)	Others (in MW)	Premium rate* (%)
1	Highly diversified portfolio	250	250	250	250	10.52
2	Standalone project in a high RE region	0	0	1000	0	22
3	Standalone project in a low RE region	0	1000	0	0	6
4	Mildly diversified portfolio	0	500	500	0	14

Source: CEEW CEF analysis

** Lower bound of the premium band generated by various statistical techniques*

4. Design inputs and methodology

4.1 Methodology

Each RE generator in Gujarat was analysed to check for monthly/quarterly trends in actual and scheduled generation. However, to elicit a higher insurable interest from developers and investors, and to pool risks among generators, pricing was targeted at a circle level to get some geographical spread.

Premium for each circle are calculated as the product of frequency of curtailment and severity of loss. Due to higher chances of moral hazard, the severity of loss is not modelled as a random variable. Instead, it is assumed to be the product of scheduled generation and unit tariff rate mentioned in the PPA.

The probability/frequency of curtailment is estimated using a combination of techniques due to the poor quality and quantity of data. The techniques used include time series modelling such as Autoregressive integrated moving averages (ARIMA), along with exponential smoothing, Holt-Winters seasonal method, and simple averages. Different techniques are used for different time series. An additional loading of 10% has been applied in risk premium to cover for administrative expenses and any residual risks (if so any) in the contract.

4.2 Data

Description

The fundamental data blocks of this instrument are day-ahead scheduled generation and actual generation (injected into the grid) at the project and substation level. While the day-ahead scheduled generation is available at the 15 minutes time block level, the actual electricity injected is taken at the monthly level since actual electricity injection at such a granular level is not yet available in the public domain. **The data used is from January 2015 to July 2017 for all of the RE projects located in Gujarat. For some generators, data was unavailable for all the months under the specified period.**

Both day-ahead and final implemented schedule are analysed to ascertain a better baseline to estimate curtailment. However, this analysis is based on the day-ahead schedule (Annexure 2).

Why Gujarat?

Gujarat is one of the leading RE states in India in terms of both installed capacity and RE policies and regulation. It has one of the highest rated discoms in India (Ministry of Power 2017), separate feeders for agricultural consumers (Vora 2017), one of the most transparent SLDC operations, and the most robust transmission planning system in the country.[12]

Chhattisgarh is another state that provides data on scheduled electricity at the 15-minute level. While designing the GIG we aimed to use data from both states, but the minimum data points required to design the instrument beyond just the scheduled generation were available only for Gujarat. Unfortunately, the Gujarat SLDC has stopped updating 15-minutes scheduling data as of July 2017.

Limitations of the data

The data used in designing this instrument has many limitations. First, the number of data points is limited. Data is available only for 31 months for each generator connected at a substation. This adversely affects the confidence with which future curtailment rates can be forecast.

Secondly, despite six revisions being allowed between the day-ahead and implemented schedules, the day-ahead schedule is used. The implemented schedule is meant to reflect the best picture of the electricity scheduled for a generator but in the records available it was changed weeks after the date of generation. The difference in the two schedules is meant to be due to the intra-day revisions that generator makes on the day due to the change in resources such as wind speeds and solar irradiation. However, due to post-dated changes in the implemented schedule, its credibility was questionable.

Third, since 15-minute level data is not available for actual electricity injected, in cases where the monthly

> Since 15-minute level data is not available for actual electricity injected, in cases where the monthly electricity injection is lower than the aggregated scheduled data, this instrument assumes the entire shortfall to be due to curtailment.

12 CEEW CEF Analysis

electricity injection is lower than the aggregated scheduled data, this instrument assumes the entire shortfall to be due to curtailment (Section 6.3, Figure 1). This situation could also arise due to the developer's inability to generate electricity at the scheduled level. It could easily be remedied if the SLDC provides the data on actual electricity injection at 15 minutes level and lists the reasons for the shortfall in the injected electricity against the scheduled electricity.

Fourth, the premiums calculated in this report are offered at the circle level (a locational variable) and the technology type (wind and solar). However, the real offering of this instrument is envisioned as different premiums for a unique combination of a generator and a substation.

5. Grid integration guarantee (GIG): Additional benefits

The GIG also informs the pace of sustainable RE capacity addition; calculates a high-frequency, local, and market-based cost of grid integration; and moves older and expensive RE capacities to a higher and stable equilibrium.

5.1 Informing the pace of sustainable RE capacity addition

The risk premiums on the GIG would inform policymakers about the feasible pace of RE capacity additions. A higher risk premium will signal that the transmission and despatch capability is relatively weak at the location for which insurance is sought. This can help plan the locations of capacity addition and the transmission infrastructure upscaling schedule, and consider support for projects in sites where the risk posed is significant.

5.2 Calculating a high-frequency, local, and market-based cost of grid integration

The GIG can help in quantifying the cost of grid integration since higher premiums will signal increasing congestion/backdown in certain parts of the grid to the government. The risk premiums are local and market-based, and these will be calculated through a predetermined algorithm. Therefore, this estimate of grid integration cost would be a better signal than the top-down or bottom-up estimation of the grid integration cost presently available. For example, SECI and NTPC could have avoided the postponement of their auctions (The Economic Times 2018) (Prateek 2018). If the GIG would have been offered in the market, it would help the tendering agencies in laying down a clear and predictable roadmap consistent with the capability of the grid to handle renewable energy .

5.3 Moving older and expensive RE capacities to a higher and stable equilibrium

In 2017, RE tariffs fell sharply in India and continued to fall, and discoms began contemplating renegotiating PPAs with RE developers to lower tariffs (Ramesh 2018). If the revenue of these RE plants could be preserved even if the tariff is lowered, these RE generators could lower tariffs. A GIG offering could guarantee RE generators certain units of injected electricity, with the volume and price guaranteeing returns. This process has to be carefully monitored with revenue preservation and Pareto improvements at its core; the sanctity of contracts should not be questioned.

6. Structuring

Structuring will determine the instrument's uptake by market participants such as RE investors and developers. Every subsection under structuring will have two components: how the use case of the instrument has been structured; and the different possible forms that this instrument could take depending on the insurable interest and feedback from stakeholders such as transcos and SLDCs.

6.1 Governance

The governance of this instrument has to be decided either by the state governments (in the case of state grids) and federal government (in the case of the Inter State Transmission System (ISTS) network). Governments could take up the insurance-based model or the platform model.

Insurance-based model

The government floats a tender to select an insurance company or group of insurance companies to offer this instrument. Price discovery is possible in this mode. However, considering the novelty of this instrument, insurance and reinsurance companies will have to be made familiar with the feasibility and use case.

Platform model

The government sets up a trust to perform an insurance company's role and fixes the price. There is no price discovery in this model. This model could be a better way to offer the instrument, considering the novelty of the GIG, but setting up an insurance company would require greater effort. This might be problematic considering the urgency of the situation and that more than 100 GW of solar and wind capacity must be installed and implemented by 2022 (Press Inormation Bureau 2017).

> **The GIG can help in quantifying the cost of grid integration since higher premiums will signal increasing congestion/backdown in certain parts of the grid to the government.**

6.2 Capitalisation

A well-capitalised insurance entity is expected to elicit more insurable interest due to its higher rating. The curtailment risk primarily arises from within the government, either transcos or SLDCs/RLDCs. But transcos do not make exorbitant profits and might not be in position to capitalise the facility offering GIG since the transmission business is a highly regulated business. Even if they do, they might not enjoy a very high rating, and it makes sense for the state and central governments to pitch in initial monies to capitalise the fund.

Other than the initial capital pool, RE investors and developers will be asked to pay the annual premiums upfront. Although most non-life insurance policies are offered on an annual basis, RE investors and developers could be offered a cap on long-term premiums if the governments agree to it. If agreed, this structure could nudge the government to plan the rolling out of transmission infrastructure in a transparent, well-prepared manner.

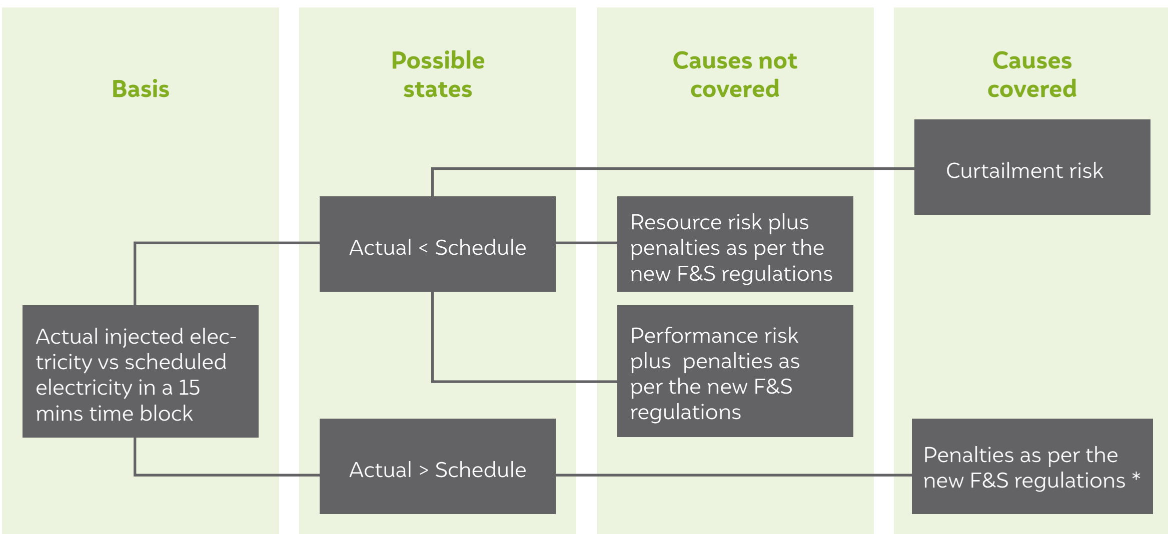
6.3 Features

Coverage

The GIG is designed to insure RE projects connected to the state grid (i.e., under the jurisdiction of state transmission companies) against the tail-end curtailment risk. The hypothesis is that state grids have relatively lower absorption capacity and face higher curtailment than the ISTS network due to the grid size of the latter. This instrument insures RE developers only against the curtailment risk, which is a post-connectivity risk. This instrument measures curtailment only against the scheduled energy; it does not cover risks such as resource risk or performance risk (Figure 1). More than 100 GW of solar and wind capacity needs to be installed and implemented by 2022 (Press Inormation Bureau 2017), and developers are concerned over the evacuation capacity of even the ISTS network (Rajeshwari 2018); therefore, this instrument could, at least, be piloted with the capacities connected to the ISTS network.

Coverage could range from 100 per cent of the revenue loss to the developer due to curtailment to 10 per cent

Figure 1: The grid integration guarantee (GIG) only covers the curtailment risk



Source: CEEW CEF analysis

** Penalties are not covered in the current pricing but could be covered*

Table 3: A sample case showing calculation of payouts and annual reconciliation

Month*	Scheduled generation (kWh)	Actual generation (kWh)	Curtailed generation	Tariff (INR/kWh)	Potential compensation
Month 4	120	100	20	3	60
Month 9	120	160	–40	3	0
End of year	320	220	–20		0

Source: CEEW CEF analysis

** No curtailment or additional injection in other months*

Box 2: GIG could also cover for the penalties but more consultations are required

GIG could also cover for the penalties but more consultations are required to incentivise the generator to inject additional electricity compared to the scheduled injection (whenever possible) into the grid, generators could also be compensated for the penalties incurred due to this additional injection but not for the curtailment of additional injected electricity. However, this feature needs to be further discussed with important stakeholders, especially SLDCs and SERCs, since it could undermine the forecasting and scheduling regulations. Since the insuring facility will settle the claims annually, this would help in lowering down compensation related pay-outs in earlier months. (See a sample calculation in Table 4.)

(Figure 1). This instrument would have a provision where the first loss of a certain estimate (10 per cent per payment cycle) is borne by the insured RE developers/ investors. However, the major value addition of the GIG is its coverage of tail-end curtailment risk.

Premium rates

The premium rates for solar plants are not calculated as the measured curtailment for various solar generators come out to be negligible across all circles in Gujarat. This can be attributed to the low and more disaggregated nature of solar capacity in the period under evaluation (January 2015 to July 2017) and to the poor quality of the data. Premium rates for the wind sector are divided into four circles: Amreli, Anjar, Junagadh, and *others* (Table 5). The *others* category includes all circles except the three circles for which separate premium rates are listed. *These values are only indicative in nature and should not be taken as a substitute for the technical pricing required for a marketable instrument.*

Also, a range of premiums are given for every circle (Table 5). This is due primarily to the poor quality of the data. Various statistical techniques are used to mitigate the issues around poor quality and range of premiums are essentially a product of the technique used.

Payout frequency

The ideal payout frequency of an instrument such as the GIG that aims to smoothen and protect the cash flows of RE investors and developers should be linked to the interest payments to the lenders. The frequency of interest payments is usually customised, monthly or quarterly, and depends on the comfort of lenders with the promoters. However, a higher curtailment in the initial months of a year resulting in a payout from the insuring facility could be followed by electricity injection in excess of the scheduled injection. *Since no developer/investor would return the portion of payout to them, the GIG is structured to have an annual reconciliation to control for the explained situation (see Table 3 for a sample calculation).*

Table 4: A sample case showing calculation of payouts with GIG covering penalties

Month*	Scheduled generation (kWh)	Actual generation (kWh)	Curtailed generation	Penalties (INR 1.5/kWh) (if any)	Tariff (INR/kWh)	Potential compensation
Month 4	80	60	20	0**	3	60 + 0
Month 9	80	110	–30	45	3	0+ 45
End of year	160	170	–10			0 + 45

** No curtailment or additional injection in other months*

*** No penalties in the case of curtailment*

Table 5: Range of premium rates for different circles for wind generators

Coverage	Premium rates	Circles			
		Amreli	Anjar	Junagadh	Others
100%	Lower Bound	12%	6%	22%	2%
	Higher Bound	18%	20%	29%	3%
90%	Lower Bound	11%	5%	20%	2%
	Higher Bound	16%	18%	26%	3%
80%	Lower Bound	10%	5%	18%	1%
	Higher Bound	14%	16%	23%	2%
70%	Lower Bound	9%	4%	15%	1%
	Higher Bound	13%	14%	21%	2%
60%	Lower Bound	7%	4%	13%	1%
	Higher Bound	11%	12%	18%	2%
50%	Lower Bound	6%	3%	11%	1%
	Higher Bound	9%	10%	15%	1%

Source: CEEW CEF analysis

Process to apply for GIG

The RE developers/investors seeking to insure their RE assets from the curtailment risk could insure their projects once they have the required PPA and connectivity and bay agreements in place. Since the GIG is to be offered only post-bid, its mere availability would influence how RE investors structure their terms. Alternatively, the GIG could be offered when requests for proposals are issued.

Documents needed to avail GIG

Power purchase agreements (PPAs)

Interested RE developers/investors have to have a legally binding and valid PPA for the to-be-insured capacities to approach the facility. The tariff price mentioned in the PPA would directly affect the payout to the RE developer. Since higher capacities signed at higher tariffs face a higher commercial curtailment risk, the pilot instrument will offer discriminatory premiums for capacities signed at higher tariffs but that has not been included in the pricing calculated in this working paper. Other than the commercial curtailment risk, the RE capacities signed at higher tariffs with the same level of curtailment will result in higher payouts. Even from the risk management perspective, the facility will require higher capital provisioning buffers. This will automatically increase the premium prices for these capacities.

The pilot of this instrument will be limited by its initial capital provisioning. The insuring facility with this limited capital could only stand as a creditworthy agency if it diversifies its risk among the capacities signed at both higher and lower tariffs and across different offtakers in various states.

Transmission-related approvals

Since the GIG only covers curtailment risk, which is de facto post-connectivity risk, the insuring facility will require the various transmission-related approvals (connectivity agreement, Bay agreements, and any final approval) clearly showing that the to-be-insured RE project is energised and has started generating and injecting electricity into the grid. Delays in access to transmission networks is outside the scope of this guarantee. These documents clearly list the substations to which insured RE projects are to be connected and the locations of these substations. Since the GIG premium has a strong dependence on the location variable, the location of the substation is critical information for the facility (Table 5).

6.4 Required technology infrastructure

Since power systems are already quite sophisticated, the additional technology infrastructure required for the insurance company to monitor and validate claims is not large. The only obstacle that could arise in the swift sharing of information generated in various parts of the grid with the insurance company is the willingness of grid operators (SLDCs, RLDCs, and NLDCs) and transcos to share the required information. Transcos could start charging for the data provided to insurance companies. This could nudge these entities to share the data generated on their systems. Claimants (RE developer/ investor), as beneficiaries, would share the information on curtailment with the insurance company when they apply for the payout.

7. Drivers for the uptake of GIG

7.1 Making transcos more accountable

Grid planning and grid operations are two different functions and ought to be operated in isolation of each other. Unfortunately, this is not the case in India where the grid operator (SLDCs) are part of the local transmission utility (grid planning entity). In most cases, an SLDC is housed inside the premises of its respective TRANSCO. *Since transcos or governments on their behalf will capitalise the initial fund of the GIG, it will kick-start a virtuous cycle where transcos will start accounting for their commissioning timelines before they grant connectivity to the RE generator.*

7.2 Debate on the feasibility of must run has started

Transmission system operators operate based on the principle of the merit order dispatch. Given the high RE tariffs in years gone by, these would not have been dispatched as per the rules. To deal with this issue, RE power plants (except biomass power plants with installed capacity of 10 MW and above) are accorded 'must run' status under Indian electricity regulations (Central Electricity Regulatory Commission 2017). The must run status ensures the offtake of RE sources and has played an instrumental role in scaling up RE generation. With the increased competitiveness of RE generation, policy support in the form of must run status for RE could be withdrawn with the dispatch becoming completely market-determined, as outlined in the draft National Energy Policy released in June 2017 (NITI Aayog 2017). The state of Madhya Pradesh withdrew must run status for RE generation through a draft order in 2017 before reinstating it later in the year amid representations from the industry (Jai 2017). These developments are indicative of the potential for gradual withdrawal of the must run status for RE as the market matures.

The grid operators can only curtail RE sources in the case of technical constraints. Since the nature of curtailment risk is slowly changing from commercial to technical, the must run status has not been of much utility to RE developers in instances of curtailment (Viswamohanan, Curtailing renewable energy curtailment 2018). Renewable energy developers, especially wind generators, have been reluctant to implement forecasting and scheduling regulations (Central Electricity Regulatory Commission 2017). *If the must run status is withdrawn, developers might opt for the GIG.*

7.3 Implementation of regulatory infrastructure: Forecasting and scheduling regulations

Some RE generators are reluctant to implement forecasting and scheduling regulations for their plants. In states such as Madhya Pradesh, where there are no regulations, the SLDC has not been able to persuade developers to install communication systems and submit daily schedules.[13] Although all states have notified these regulations in the last year and a half, Karnataka and Andhra Pradesh still allow generators to submit aggregated day-ahead schedules of plants connected at different substations in the grid, defeating the purpose of these regulations in the first place. Once these stabilise, the quality of forecast would improve considerably, since these regulations have penalties beyond a quantum of deviation. *This better quality of forecasting and scheduling would improve the workings of the GIG as timely scheduling and accurate forecasts are its foundational bedrock.*

The state of Madhya Pradesh withdrew must run status for RE generation through a draft order in 2017 before reinstating it later in the year amid representations from the industry. These developments are indicative of the potential for gradual withdrawal of the must run status for RE as the market matures. If the must run status is withdrawn, developers might opt for the GIG.

13 Minutes from CEA's RESD Committee report

7.4 More accurate and granular information

A major limitation of the data used in designing this instrument is that its measurement of curtailment includes instances where generators were not able to inject electricity into the grid due to resource constraints and quality issues. Data around electricity injected at 15 minutes level is paramount to estimate instances of curtailment. *As forecasting and scheduling regulations would stabilise and the Indian grid operators move towards smaller time blocks for electricity despatch, estimating quantum and instances of curtailment would become easier and more accurate.*

The Indian Space Research Organisation (ISRO) is helping states to harmonise and systematise the information around their power infrastructure (Department of Space ISRO 2017). A clear mapping of substations, power lines, tie lines, and towers would ease the pressure on the agency offering the GIG to map these infrastructure subcomponents clearly. Such tools could be used to reconcile the inconsistency in jurisdictions between transcos and general state administrations.

8. Barriers to the uptake of GIG

8.1 Political economy of data transparency

Paucity of granular data is a big barrier to the optimal design and structuring of the GIG. The availability of granular data may make certain actors more accountable and uncover inefficiencies in certain parts of the power despatch value chain. The adversely affected parties might resist the making available of data, possibly even to private insuring facilities.

8.2 Not enough insurable interest

The RE investors and developers might not have the financial space to buy coverage for curtailment risk. In India, the nature of curtailment risk is slowly evolving from commercial to technical. Interest from RE investors and developers to opt for an instrument such as the GIG would depend on the proportional duration of their skin in the well-functioning of these RE projects during the course of their life. For example, lenders who are expecting to offload their loan portfolios in five or six years might not be interested in the curtailment risk beyond their holding period. Similarly, if promoters and private equity (PE) investors are expecting to offload their equity investments either through capital markets or private transactions to institutional investors in a certain time period, they might not want to invest in covering this risk, especially as tariff competitiveness is high and growing further.

8.3 Inertia in older PPAs

From the perspective of commercial curtailment risk, older RE capacities signed at higher tariffs face higher commercial curtailment risk than recently tendered and installed RE capacities. Many businesses and RE developers built these older capacities to avail of tax benefits such as accelerated depreciation (IISD 2015). Lower generation due to higher curtailment might not affect this set of RE investors and developers and businesses that set up these capacities to meet their captive demand.

Also, since the reverse auction regime was introduced only in early 2017 (Ray 2017), wind capacities installed in the FIT regime might have higher margins built in the financial model of these projects due to the lack of any competitive forces. These developers might not see any value in opting for the GIG. However, these developers might not have factored in the extreme curtailment that they could face due to commercial and technical reasons.

8.4 National security issues

Power infrastructure is critical to the well-functioning of an economy. Critical infrastructure such as power utilities has been under constant threat from the cyberattacks across countries (In a first, U.S. blames Russia for cyber attacks on energy grid 2018) (Dunietz 2017). Data sharing will have to be done in a secure and prudent manner. Even if government agencies decide not to make the data available in the public domain, it could be made available to the insuring facility on a selective basis. If the government decides to opt for a trust-based model (Section 6), it could make the data available to the insuring facility (in this case, a government-owned entity).

9. Next steps

The initial design of the instrument is mostly indicative. Consultations with developers, transcos, and political executives will be necessary to test and socialise the design and make the analysis of a use case more robust.

9.1 Gauging insurable interest

Different RE developers/investors have installed their capacities in different years and work on different financial models. Some have the advantage of a portfolio of projects while others have a smaller number of RE projects. For some investors and developers, liquidity issues due to curtailment in the high wind season could be an issue, whereas for others the issue might be overall revenue loss due to annual curtailment. The instrument offering needs to be structured accordingly.

9.2 Model the future grid

In this first version of the GIG, risk premiums are calculated on the basis of forecasting the past data. However, the grid could change profoundly after an inflection point as more RE capacity comes online. Instead of relying on past data, there is a need to model the grid in its future state. This would require significant modelling effort and buy-in from the state agencies to get information on their prospective planning.

9.3 Urging states to make grid dispatch data available

The initial use case of the GIG is designed for the state of Gujarat. However, since the framework is easily replicable in other states, agencies such as SLDCs and transcos of other states could be urged to make available the data around scheduling and actual injection. This will help the insuring facility elicit a higher insurable interest. It will also help RE investors and developers in planning their portfolio of projects across Indian states.

In this first version of the GIG, risk premiums are calculated on the basis of forecasting the past data. However, the grid could change profoundly after an inflection point as more RE capacity comes online. Instead of relying on past data, there is a need to model the grid in its future state.

10. References

Anjali Viswamohanan, Manu Aggarwal. 2018. *Curtailing renewable energy curtailment*. New Delhi: CEEW. Accessed June 2019. http://www.ceew.in/sites/default/files/Curtailing_Renewable_Energy_Curtailment_27Jun18.pdf.

Anjali Viswamohanan, Manu Aggarwal. 2018. Curtailing renewable energy curtailment. New Delhi: CEEW. Accessed June 2019. http://www.ceew.in/sites/default/files/Curtailing_Renewable_Energy_Curtailment_27Jun18.pdf.

Asian Power. 2016. *China reveals new quota of 1,800-2,000 minimum utilisation hours for wind power.* 17 June. https://asian-power.com/ipp/in-focus/china-reveals-new-quota-1800-2000-minimum-utilisation-hours-wind-power.

Bureau, Press INformation. 2017. “Year end review 2017-MNRE.” *www.pib.nic.in*. 27 December. Accessed June 2019. http://pib.nic.in/newsite/PrintRelease.aspx?relid=174832.

Business Standard. 2017. “Power Ministry Proposes Compensation for Grid Curtailment; Positive for Renewables.” *Business standard*, 26 May. http://www.business-standard.com/article/news-cm/power-ministry-proposes-compensation-for-grid-curtailment-positive-for-renewables-117052600174_1.html.

Central Electricity Regulatory Commission. 2010. New Delhi. Accessed June 2019. https://powermin.nic.in/sites/default/files/uploads/Indian_Electricity_Grid_Code.pdf.

Central Electricity Regulatory Commission. 2012. *Notification*. New Delhi: Central Electricity Regulatory Commission. http://www.cercind.gov.in/2016/regulation/19.pdf.

Central Electricity Regulatory Commission. 2015. *Notification*. New Delhi: Central Electricity Regulatory Commission. http://www.cercind.gov.in/2015/regulation/Noti13.pdf.

Central Electricity Regulatory Commission. 2016. *Notification*. New Delhi: Central Electricity Regulatory Commission. http://www.cercind.gov.in/2016/regulation/124_1.pdf.

Central Electricity Regulatory Commission. 2017. *Order*. New Delhi: Central Electricity Regulatory Commission. http://www.cercind.gov.in/2017/orders/79_rc.pdf.

Central Electricity Regulatory Commission. 2017. *Petition*. New Delhi: Central Electricity Regulatory Commission. Accessed 2019. http://www.cercind.gov.in/2017/orders/179MP2015.pdf.

Central Electricity Regulatory Commission. 2017. *Statement of reasons*. New Delhi: CENTRAL ELECTRICITY REGULATORY COMMISSION. http://www.cercind.gov.in/2017/regulation/SOR131.pdf.

CERC. 2018. *Notification (Draft)*. New Delhi: Central Electricity Regulatory commission. http://cercind.gov.in/2018/draft_reg/Noti27.pdf.

CERC. 2017. *Notification*. New Delhi: Central Electricity Regulatory Commission. http://www.cercind.gov.in/2016/regulation/19.pdf.

Chawla, Kanika. 2016. *Money talks? Risks and responses in India’s solar sector.* New Delhi: CEEW.

Deign, Jason. 2017. *China Faces an Uphill Renewable Energy Curtailment Challenge*. 17 November. https://www.greentechmedia.com/articles/read/china-faces-uphill-renewable-energy-curtailment-challenge#gs.XVFg9dg.

Department of Space ISRO. 2017. *ISRO Develops MSETCL GIS Portal*. September. Accessed 2019. https://www.isro.gov.in/isro-develops-msetcl-gis-portal.

Dunietz, Jesse. 2017. “Is the Power Grid Getting More Vulnerable to Cyber Attacks?” *Scientific American*, 23 August. https://www.scientificamerican.com/article/is-the-power-grid-getting-more-vulnerable-to-cyber-attacks/.

GERC. 2016. *Order*. Gandhinagar: Gujarat Electricity Regulatory Commission. http://gercin.org/uploaded/document/07c74229-5dc4-4406-89d3-25a82fa0931b.pdf.

2019. *Global greenhouse gas emissions data*. 28 May. Accessed June 2019. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

IISD. 2015. *Case study: India’s accelerated depreciation policy for wind energy.* Canada: IISD. https://www.iisd.org/sites/default/files/publications/india-accelerated-depreciation-policy-wind-energy-case-study.pdf.

2018. *In a first, U.S. blames Russia for cyber attacks on energy grid*. 16 March. Accessed 2019. https://in.reuters.com/article/usa-russia-sanctionsenergygrid/in-a-first-u-s-blames-russia-for-cyber-attacks-on-energy-grid-idINKCN1GR2RE.

IRENA. 2018. *Renewable capacity statistics 2018*. IRENA. http://www.irena.org/publications/2018/Mar/Renewable-Capacity-Statistics-2018.

Jai, Shreya. 2017. "MP provides must-run status to renewable energy but imposes extra charges." *Business standard*, 06 December. MP provides must-run status to renewable energy but imposes extra charges.

John, Jeff St. 2016. *As Germany Curtails Wind and Solar, Billion-Euro Grid Projects Help Bring More Green Power On-Line*. 28 April. https://www.greentechmedia.com/articles/read/as-germany-curtails-wind-and-solar-billion-euro-grid-projects-seek-to-bring#gs.cD3roJM.

Kanika Chawla, Manu Aggarwal. 2016. *Anatomy of a Solar Tariff: Understanding the decline in solar bids globally.* CEEW policy brief, New Delhi: CEEW. Accessed June 2019.

KERC. 2016. *www.karnataka.gov.in*. 30 November. Accessed 2019. http://www.karnataka.gov.in/kercold/Regulations/Forecast_Sheduling-Extension_of_Date.pdf.

Lori Bird, Jaquelin Cochran, and Xi Wang. n.d. *Wind and Solar Energy curtailment: Experiences and practices in the United States*. NREL. Accessed June 2019. https://www.nrel.gov/docs/fy14osti/60983.pdf.

Michael Joos, Iain Staffell. 2018. "Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany." *Science Direct* 45-65. https://www.sciencedirect.com/science/article/pii/S1364032118300091.

Ministry of Power. 2019. *Distribution*. June. Accessed 2019. https://powermin.nic.in/en/content/distribution-0.

Ministry of Power. 2017. *State Distribution Utilites*. New Delhi: Ministry of Power. http://www.pfcindia.com/DocumentRepository/ckfinder/files/GoI_Initiatives/Annual_Integrated_Ratings_of_State_DISCOMs/5th_rating_booklet_2017.pdf.

MNRE. 2016. *Backing down oof solar projects*. New Delhi: MNRE. Accessed June 2019. https://mnre.gov.in/file-manager/UserFiles/Backdown-of-solar-projects.pdf.

Mondal, Debapriya. 2017. "Progress of green energy corridor very different on paper and on ground: Mercom Capital." *The Economic Times*, 03 January. Accessed 2019. https://energy.economictimes.indiatimes.com/news/renewable/progress-of-green-energy-corridor-very-different-on-paper-and-on-ground-mercom-capital/56316338.

Mulder, F.M. 2014. "Implications of diurnal and seasonal variations in renewable energy generation for large scale energy storage." *Journal of renewable and sustainable energy*. https://aip.scitation.org/doi/full/10.1063/1.4874845.

2019. *NDC Registry (interim)*. Accessed June 2019. https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx.

NITI Aayog. 2017. *Draft National Energy Policy*. New Delhi: NITI Aayog. http://niti.gov.in/writereaddata/files/new_initiatives/NEP-ID_27.06.2017.pdf.

Prateek, Saumy. 2018. *Lack of ISTS Connectivity Results in Delay of 7 GW of Solar Auctions*. 21 May. https://mercomindia.com/ists-connectivity-delay-7gw-solar-auctions/.

Press Information Bureau. 2015. "UDAY (Ujwal DISCOM Assurance Yojana) for financial turnaround of Power Distribution Companies ." *www.pib.nic.in*. 05 November. Accessed June 2019. http://pib.nic.in/newsite/PrintRelease.aspx?relid=130261.

Press Inormation Bureau. 2017. "Government announces Trajectory to achieve its targets of commissioning 100 GW of Solar generating capacity and 60 GW of Wind power by 2022 ." *www.pib.nic.in*. 24 November. http://pib.nic.in/newsite/PrintRelease.aspx?relid=173830.

Rajasthan Electricity Regulatory Commssion, Jaipur. 2017. "RAJASTHAN ELECTRICITY REGULATORY COMMISSION JAIPUR." In RERC order dated 29 November 2017, in the matter of Renew & Ors. v. Rajasthan SLDC & Ors., it was contended that backdown from wind power generators over thermal generators during high power demand season was for commercial reasons – to reduce the NR s.

Rajeshwari, Ankita. 2018. "Indian Solar Developers Urge MNRE to Postpone Auctions Due to Transmission Issues." *Mercom India*, 15 May. https://mercomindia.com/solar-developers-letter-mnre-postpone-auctions/.

Ramesh, M. 2018. "PPA renegotiation: NLC ultimatum to Rajasthan govt on two projects." *The Hindu Business Line*, 08 January. https://www.thehindubusinessline.com/companies/ppa-renegotiation-nlc-ultimatum-to-rajasthan-govt-on-two-projects/article10020407.ece.

Ray, Suchetana. 2017. "Wind tariff in India falls to all-time low of Rs 3.46 per unit." *Hindustan Times*, 24 February. https://www.hindustantimes.com/business-news/wind-tariff-in-india-falls-to-all-time-low-of-rs-3-46-per-unit/story-vl7yh6y6siQRLsMPqdIvsK.html.

RERC. 2017. *Order.* Jaipur: RAJASTHAN ELECTRICITY REGULATORY COMMISSION JAIPUR. http://rerc.rajasthan.gov.in/Orders/Order444.pdf.

Rewa ultra mega solar limited. 2017. *Power purchase agreement*. Madhya Pradesh: Rewa ultra mega solar limited. http://rumsl.com/pdf/RUMS%20Model%20PPA.pdf.

Sam Fankhauser, Aditi Sahni, Annie Savvas and John Ward. 2015. *Where are the gaps in climate change?* London: London School of Economics and Political Science. http://eprints.lse.ac.uk/64179/7/Fankhauser_Where%20are%20gaps.pdf.

Shri Gireesh B. Pradhan, Shri A.K. Singhal, Shri A.S. Bakshi, Dr. M.K. Iyer. 2016. “Statement of reasons.” New Delhi. Accessed June 2019. http://www.cercind.gov.in/2016/regulation/SOR123.pdf.

Smiti. 2017. *Indian Ministry Warns States Against Solar Power Curtailment*. 23 October. Accessed June 2019. https://cleantechnica.com/2017/10/23/indian-ministry-warns-states-solar-power-curtailment/.

Sraisth. 2017. “NTPC cancels Andaman’s energy storage tender.” *pv magazine*, 12 October. https://www.pv-magazine-india.com/2017/10/12/ntpc-cancels-andamans-energy-storage-tender/.

The Economic Times. 2018. “BSES Delhi discoms procure 200 Megawatt wind power at low rate.” *EnergyWorld.com*, 04 April. https://energy.economictimes.indiatimes.com/news/renewable/bses-delhi-discoms-procure-200-megawatt-wind-power-at-low-rate/63608018.

Press Trust of India. 2018. “NTPC puts off solar projects auction amid developers concerns on evacuation.” *The Economic Times*, 19 May. Accessed 2019. https://energy.economictimes.indiatimes.com/news/renewable/ntpc-puts-off-solar-projects-auction-amid-developers-concerns-on-evacuation/64234928.

TNERC. 2015. TAMIL NADU ELECTRICITY REGULATORY COMMISSION. http://www.tnerc.gov.in/orders/commn%20order/2015/Indian%20-%20D%20R%20P%20No.%2014%2028%2021%2022%2023%20and%2045.pdf.

TNERC. 2017. *Order.* TAMIL NADU ELECTRICITY REGULATORY COMMISSION. http://www.tnerc.gov.in/orders/commn%20order/2017/Solar-IAN01%20of%202017.pdf.

United States Environmental Protection Agency. 2017. *Global Greenhouse Gas Emissions Data*. 27 September. Accessed June 15, 2019. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

Vora, Rutam. 2017. “How Gujarat became a power surplus State.” *Business Line*, 25 November. https://www.thehindubusinessline.com/news/national/How-Gujarat-became-a-power-surplus-State/article20796535.ece.

11. Annexures

Curtailment estimates in Gujarat

Table A1: Curtailment ratios for different circles in Gujarat

Month	Amreli (%)	Anjar (%)	Bharuch (%)	Gondal (%)	Jambuva (%)	Jamnagar (%)	Junagadh (%)	Mehrana (%)	Mehsana (%)	Palanpur (%)	Surendranagar (%)	Unknown (%)	Grand Total (%)
Jan 2015	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%
Feb 2015	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mar 2015	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Apr 2015	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
May 2015	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jun 2015	24%	0%	6%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%
Jul 2015	0%	0%	0%	0%	0%	17%	0%	0%	0%	17%	0%	0%	0%
Aug 2015	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%
Sep 2015	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Oct 2015	0%	4%	0%	0%	0%	0%	30%	0%	2%	0%	0%	0%	0%
Nov 2015	16%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dec 2015	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jan 2016	0%	0%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%
Feb 2016	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%
Mar 2016	0%	0%	0%	0%	0%	7%	0%	0%	0%	0%	0%	0%	0%
Apr 2016	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%
May 2016	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jun 2016	25%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jul 2016	46%	18%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aug 2016	53%	16%	0%	0%	0%	29%	0%	0%	0%	0%	0%	0%	0%
Sep 2016	32%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%
Oct 2016	24%	0%	0%	26%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Nov 2016	16%	0%	0%	22%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dec 2016	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jan 2017	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Feb 2017	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mar 2017	2%	0%	0%	0%	0%	7%	0%	0%	0%	0%	0%	0%	0%
Apr 2017	56%	29%	0%	18%	0%	0%	53%	0%	0%	0%	34%	0%	1%
May 2017	0%	3%	0%	0%	0%	26%	29%	0%	0%	0%	0%	0%	0%
Jun 2017	0%	11%	0%	0%	0%	8%	30%	0%	0%	0%	0%	0%	0%
Jul 2017	4%	28%	0%	0%	0%	22%	31%	4%	0%	0%	0%	0%	12%
Grand Total	1%	0%	0%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%

Source: CEEW CEF analysis; Gujarat SLDC.

Average for the month	Amreli	Anjar	Bharuch	Gondal	Jambuva	Jamnagar	Junagadh	Mehrana	Mehsana	Palanpur	Suren-dranagar	Unknown	Grand Total
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%
4	18%	3%	0%	18%	0%	0%	36%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	15%	6%	0%	0%	0%	0%	0%	0%
6	17%	0%	0%	0%	0%	0%	9%	0%	0%	0%	0%	0%	0%
7	18%	14%	0%	0%	0%	14%	11%	0%	0%	0%	0%	0%	2%
8	14%	3%	0%	0%	0%	25%	0%	0%	0%	0%	0%	0%	0%
9	10%	0%	0%	0%	0%	27%	0%	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	26%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11	16%	0%	0%	22%	0%	0%	0%	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grand Total	1%	0%	0%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%

Source: CEEW CEF analysis; Gujarat SLDC.

Year	Amreli	Anjar	Bharuch	Gondal	Jambuva	Jamnagar	Junagadh	Mehrana	Mehsana	Palanpur	Suren-dranagar	Unknown	Grand Total
2015	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2016	7%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
2017	9%	8%	0%	0%	0%	5%	24%	0%	0%	0%	0%	0%	0%
Grand Total	1%	0%	0%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%

Source: CEEW CEF analysis; Gujarat SLDC.

Quarter	Amreli	Anjar	Bharuch	Gondal	Jambuva	Jamnagar	Junagadh	Mehrana	Mehsana	Palanpur	Suren-dranagar	Unknown	Grand Total
Q1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Q2	10%	0%	0%	1%	0%	0%	16%	0%	0%	0%	0%	0%	0%
Q3	15%	6%	0%	0%	0%	20%	5%	0%	0%	0%	0%	0%	0%
Q4	5%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grand Total	1%	0%	0%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%

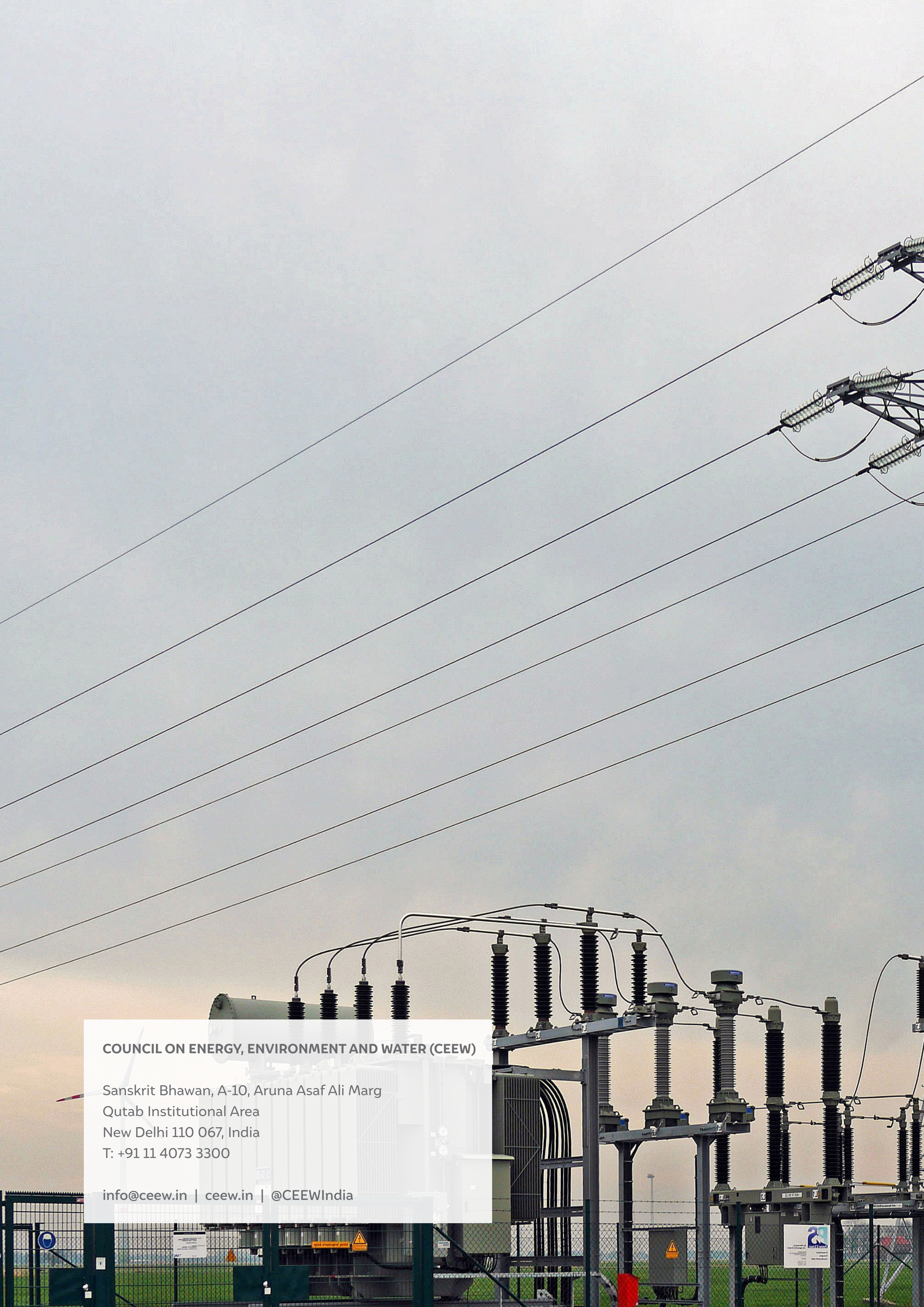
Source: CEEW CEF analysis; Gujarat SLDC.

Difference between the curtailment rates on the basis of day-ahead and final implemented schedule

Table A2: Difference in the curtailment rates based on day-ahead and final implemented schedules

Month	Amreli	Anjar	Bharuch	Gondal	Jambuva	Jamnagar	Junagadh	Mehrana	Mehsana	Palanpur	Suren-dranagar	Unknown
Jan 2015	0%	0%	0%	20	-	2%	0%	0%	0%	0%	0%	0%
Feb 2015	-8%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Mar 2015	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Apr 2015	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
May-15	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Jun-15	-10%	0%	0%	-	0%	-7%	0%	0%	0%	0%	0%	0%
Jul-15	0%	-4%	0%	-	0%	6%	0%	0%	0%	17%	-8%	0%
Aug-15	0%	0%	0%	-	0%	-3%	0%	0%	0%	0%	0%	0%
Sep-15	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Oct-15	-19%	4%	0%	-	0%	0%	30%	0%	-1%	0%	0%	0%
Nov-15	-6%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Dec-15	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Jan-16	-7%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Feb-16	-8%	0%	0%	-	0%	0%	2%	0%	0%	0%	0%	0%
Mar-16	0%	0%	0%	-	0%	7%	0%	0%	0%	0%	0%	0%
Apr-16	0%	-2%	0%	-	0%	-1%	-7%	0%	0%	0%	0%	0%
May-16	-6%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Jun-16	-3%	-3%	0%	-	0%	-1%	0%	0%	0%	0%	0%	0%
Jul-16	-5%	-2%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%
Aug-16	0%	-6%	0%	0%	0%	-1%	-8%	0%	0%	0%	0%	0%
Sep-16	0%	-1%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%
Oct-16	0%	0%	0%	-2%	0%	0%	0%	0%	0%	-33%	0%	0%
Nov-16	0%	0%	0%	-5%	0%	0%	0%	0%	0%	-46%	0%	0%
Dec-16	0%	0%	0%	-1%	0%	0%	0%	0%	0%	-53%	0%	0%
Jan-17	-1%	0%	0%	0%	0%	0%	0%	0%	0%	–21%	0%	0%
Feb 2017	0%	0%	0%	4%	0%	0%	0%	0%	0%	–39%	0%	0%
Mar 2017	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%
Apr 2017	54%	24%	0%	18%	0%	–19%	29%	0%	0%	0%	34%	0%
May 2017	0%	3%	0%	0%	0%	9%	29%	0%	0%	0%	0%	0%
June 2017	–3%	3%	0%	0%	0%	8%	25%	0%	0%	0%	0%	0%
July 2017	–10%	10%	0%	0%	0%	22%	19%	–36%	0%	0%	–7%	0%

Source: CEEW CEF analysis; Gujarat SLDC.



COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

Sanskrit Bhawan, A-10, Aruna Asaf Ali Marg
Qutab Institutional Area
New Delhi 110 067, India
T: +91 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia