

Review

Strategic investment risks threatening India's renewable energy ambition

Hemi H. Gandhi ^{a,b,*}, Bram Hoex ^a, Brett Jason Hallam ^{a, **}^a School of Photovoltaic and Renewable Energy Engineering, University of New South Wales, Kensington, New South Wales, Australia^b Harvard John A. Paulson School of Engineering and Applied Sciences, Cambridge, MA, USA

ARTICLE INFO

Keywords:

India
Renewable energy
Investment risk
Investment risk mitigation strategies
Energy transition

ABSTRACT

India has set an ambitious renewable energy target of 450 GW by 2030. Meeting the target will require \$600 billion in financing for new generation and grid infrastructure, including \$200 billion for PV and wind capacity. Sector financing must scale rapidly to meet this target. Mobilizing needed capital will be difficult given the complex renewable energy (RE) sector investment risks. The goals of this paper are to: 1) guide stakeholders in systematically understanding these risks and 2) empower them with risk mitigation strategies. We complement this body of work by presenting Indian RE sector insights that have been distilled from 18 months of 40 primary research interviews with leading sector investors, independent power producers, consultants and policymakers.

The work begins by overviewing India's RE progress to date and motivating a systematic understanding of sector investment risks. The power sector's political-economic structure is then explained. The financial distress of India's DisCos is emphasized along with its troubling impact on RE investments. Subsequently, nine strategic sector investment risks and corresponding mitigation strategies are discussed: project development risk, offtaker risk, stranded asset risk, volume risk, curtailment, regulatory risk, inflation, exchange rate risk, and tail risk. Offtaker risk—the most significant risk—is comprehensively discussed. Finally, we raise critical questions on evolving variables that will determine the future sector risk profile. The ideas and frameworks presented herein are also relevant to emerging markets with a similar power sector structure.

1. Introduction

1.1. India's monumental energy transition

India is amidst a monumental energy transition—with global consequences. With a colossal number of 1.39 billion people [1], India's is already the world's 3rd largest energy consumer and greenhouse gas emitter (behind China and the United States). The country's demand for energy, however, has only just begun. India's per capita gross domestic product and electricity consumption are still quite modest compared to its peers, as shown in Fig. 1. The median Indian (65% of the population) still lives in a rural area, most likely as a farmer. Fewer than 3% of households own air conditioning (AC)¹ units [2]; only 2.2% have cars [3]. India's population is primed to continuously grow, industrialize, urbanize, and electrify their lives. Over the next two decades, India will urbanize 300 million people, double building space, add 640 million AC units, and add 240 million road vehicles [4]. During this period, India's new total energy demand will be 25% of the global increase in total

energy demand [4]. Meeting India's doubling electricity demand will require adding power capacity equivalent to the European Union's (EU) entire power system today [4]. Consequently, how India chooses to meet its future energy demand growth will have profound global environmental and market implications.

1.2. Rapid RE progress to-date

Rapid massive deployment of renewable energy (RE) has emerged as the centrepiece of India's energy transition strategy. RE offers India persuasive advantages versus its historical paradigm of burning imported coal: reduced electricity costs, reduced current account deficits, increased energy security, pollution mitigation and a pathway to deliver [7] on its global climate commitments [8–10]. Serious political commitment for RE began in the early 2010s [10–12] and has supercharged under the Modi government (2016–present) [8].

Policy pull [13] and market forces have unleashed rapid RE progress [14]. The present cumulative installed total photovoltaic (utility-scale

* Corresponding author. Creative Synergies Group, USA.

** Corresponding author.

E-mail addresses: hemi.gandhi@global-csg.com (H.H. Gandhi), brett.hallam@unsw.edu.au (B.J. Hallam).

¹ See Supplemental Material (SM) for a complete list of abbreviations used in this work.

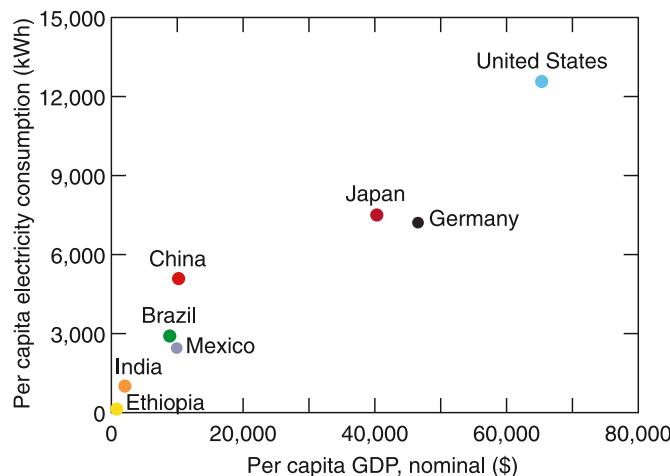


Fig. 1. Per capita electricity consumption of populous countries relative to per capita nominal GDP (current US dollars) in 2019. Data from the World Bank [5] and OurWorldInData [6].

and rooftop) and wind capacity in India is 46 GW and 40 GW, respectively [15]. Between 2012 and 2021, total photovoltaic (PV) and wind capacity increased 46× and 2× [16]. Concurrently, average utility-scale PV and wind tariffs have dropped, respectively, by 66% and 27% [17]. Utility-scale capacity and weighted average utility-scale auction tariffs are shown in Fig. 2a and b [17]. While coal still dominates India's total power capacity and energy generation mix (Fig. 3a and b) [14], PV and wind's combined share of power capacity has surpassed 20% [14]. India's installed PV and wind capacities are the fifth [4] and fourth [18] largest in the world, respectively. Recent RE tariffs of Rs 1.98–3.0/kWh (\$0.03–0.04/kWh)² are among the world's lowest [14].

We note that India—like other emerging markets with a complex investment risk environment and capital scarcity [19,20]—is presently evaluating how to attract larger RE investment while not disrupting economic growth and fossil-fuel dependent forms of economic activity [4]. The energy investment literature contains innovative statutory and contractual models for how RE investment can be stimulated in emerging economies, while harmoniously facilitating economic development reliant on conventional energy sources [21–23]. For example, Lebanon has employed upstream production sharing contracts to utilize a portion of the contractors' profits for renewable energy investments [21]. Furthermore, a model for simultaneously awarding integrated energy contracts for upstream natural gas projects and renewable energy projects in Nigeria, Myanmar and Indonesia has also been discussed [22]. We anticipate such successes to inform future RE policy design in India and other emerging markets.

1.3. 450 GW RE target

Moving forward, India has set a massive 450 GW RE capacity target for 2030, including 300 GW PV and 140 GW wind targets [24]. This target is comparable to the entire capacity of the EU's power system today [4]. Meeting this target will be a massive undertaking. Half a million acres of land must be acquired; half a billion PV modules installed, thousands of RE power plants built; existing grid infrastructure replaced and expanded. Required investment across generation and grid networks is estimated to be \$600 billion (bn), including \$200 bn for PV and wind [14]. This dwarfs the investment (\$75 bn) for new PV/wind capacity between 2010 and 2019 [14].

Mobilizing this scale of financing will be challenging for two reasons.

First, the largest source of present financing, the Indian banking system, simply doesn't have more capital to lend. The system has long been structurally fragile, is deeply hit from the Covid-19 recession, and nearing regulated lending limits for the power sector [25]. Second, RE investments are fraught with complexity and risks [26,27]. Long project delays are routine, and Power Purchase Agreements (PPAs) do not protect against inflation. The main power offtakers—State Distribution Companies (DisComs)—are delinquent in making their payments by an average of 11-months [28]. DisComs have spooked investors by cancelling signed 25-year PPAs worth billions of dollars [29]. Contract risks [29,30] are exacerbated by the weak and glacially slow Indian legal system.

For RE investors, who generally seek opportunities with stable long-term cash flows, such risks curtail their confidence in the sector and raise the sector risk premium [27,31–33]. The energy investment literature contains well developed theoretical and empirical models examining how various investment risks and risk mitigation instruments influence investor behavior when evaluating risk-return profiles [34–40]. Empirical historical studies have clearly shown that significant investment risks have deterred RE investor activity in both emerging [41–49] and developed [50–56] economies over the last two decades. It has been established that in India's case, major investment risks presently limit the capital pool available to finance India's RE transition [57,58]. This conclusion has been further buttressed by our findings from 40 primary interviews conducted for this work. Nearly all (*i.e.*, 37/40) of the leading sector authorities interviewed—private equity investors, independent power producer (IPP) Executives, consultants, and policy makers—expressed concerns about unresolved investment risks limiting long-term sector capital flow.

1.4. Goals and outline of this work

These major investment challenges raise a key question: *how will India attract the required financing to meet its ambitious 450 GW RE target?* Policy reforms to both the banking sector—to free up capital—and the RE sector—to mitigate investment risks—are no doubt imperative. It is uncertain whether, how, and when such reforms may occur. Regardless, for India to meet its target, financiers and stakeholders must be confident they can successfully navigate sector investment risks.

The goals of this paper are to 1) guide stakeholders in systematically understanding sector investment risks and 2) empower them with risk mitigation strategies. The paper builds upon theoretical and empirical studies on the impact of RE investment risks in emerging and developed economies carried out over the last two decades. We complement this body of work by presenting new insights on the Indian RE sector risks that have been distilled from 18 months of 40 primary research interviews with leading sector investors, Independent Power Producers, consultants, and policymakers. The ideas and frameworks presented herein are relevant to emerging markets with a similar power sector structure.

We proceed as follows. First, we present the political-economic structure of the Indian power sector. We highlight the sector's weakest link—DisComs—and explain their perpetual financial distress that endangers the entire power sector. Next, we discuss nine strategic RE sector investment risks and corresponding risk mitigation strategies. We comprehensively discuss offtaker risk—the most significant risk—and strategies to mitigate it. Finally, we raise critical questions on evolving variables that will determine the future sector risk profile.

2. Power sector's federal political-economic structure

We now describe the federal political-economic structure of the Indian power sector (Fig. 4), which subsumes the RE sector. For reference, the Republic of India is a federal union consisting of a central government (the Centre) and 29 states and 8 union territories.

² Throughout this work we convert Indian Rupee (INR) amounts to United States Dollars (USD) using a 73 USD/INR exchange rate.

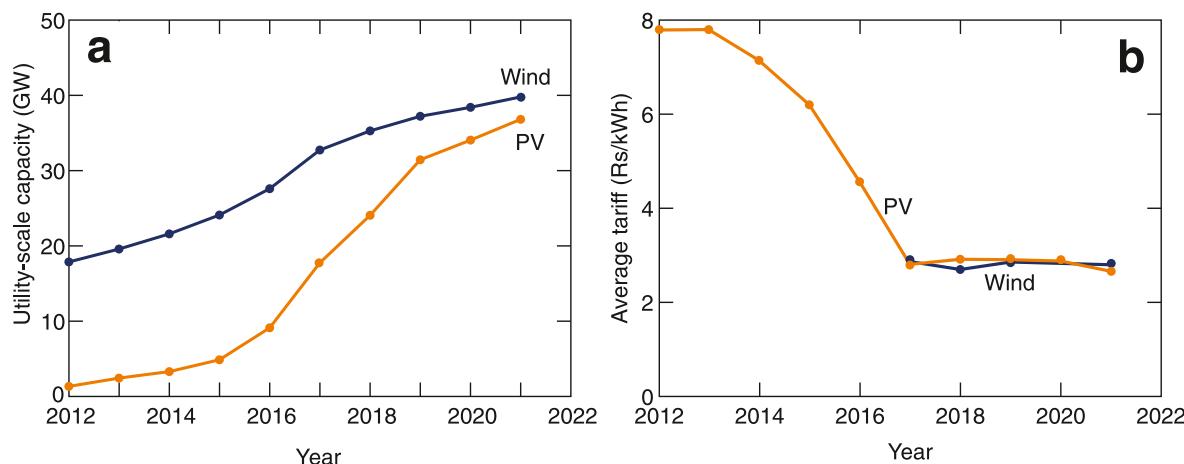


Fig. 2. Annual Indian a) cumulative installed utility-scale PV and wind capacity and b) weighted average utility-scale tariffs at auction. Data courtesy of Bridge to India.

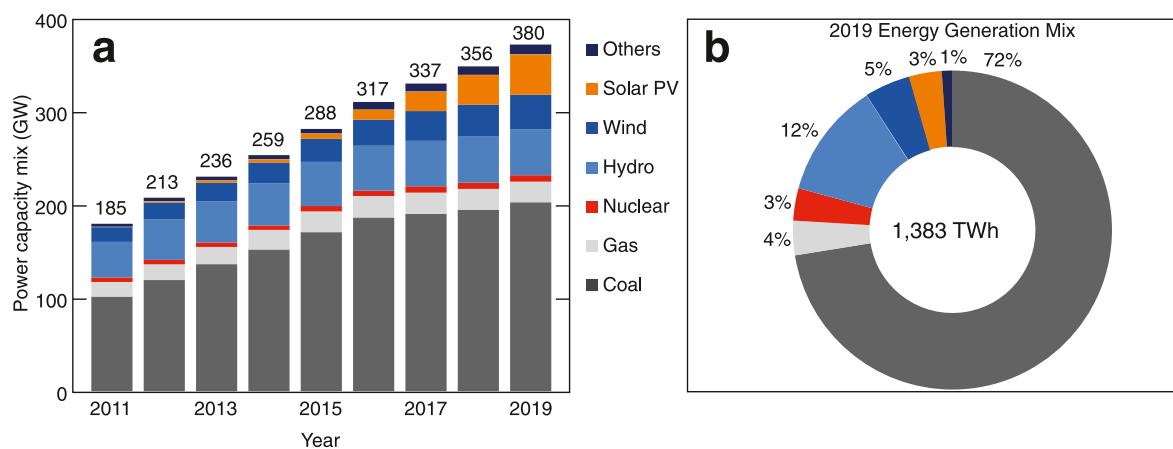


Fig. 3. India's power generation mix by a) annual cumulative capacity b) generation in 2019. PV capacity is in DC. Data courtesy of BNEF [14].

2.1. Electricity: a concurrent constitutional subject

The constitution classifies “electricity” as a “concurrent” subject [59], which grants both the central parliament and state legislatures jurisdiction over the power sector [60]. In practice, the Centre and states have distinct responsibilities and interests in the power sector. Their interests are often conflicting, creating sectoral dysfunction [61]. The Centre has authority over all international, national, and interstate power sector matters, while states have authority over state matters, including the entire distribution sector. The Centre is focused on macro issues like ensuring adequate power supply for economic growth, maintaining a reliable national grid, attracting sector investment, and meeting climate commitments. In contrast, states, via DisComs, directly supply end-consumers, who vote state politicians in and out of office. State politicians are loathe to implement major reforms—like increasing consumer tariffs to reflect true costs or privatizing DisComs—that would alienate voters.

The concurrent classification prevents the Centre from simply mandating states to improve DisComs’ finances and operations. India’s courts have not definitively proven that in the event central and state power sector laws conflict, central law will override [61]. With this ambiguity, the Centre has been careful not to impinge on state preferences and mandate nation-wide reforms that structurally address power sector dysfunction.

The Electricity Act, 2003 (EA) [62], is the primary legislation governing key power market functions. The EA is comprehensively detailed

in Supplementary Material (SM) Table I.

2.2. Relevant governmental players and IPPs

National policymaking and power sector development planning is carried out by the Ministry of Power and the Ministry of New and Renewable Energy (MNRE) determines policies related to expanding deployment of RE.

National/interstate and state regulations are determined, respectively, by the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERCs). CERC regulates licenses and tariffs of Generating Companies (GenCos) and their electricity generation and trading activities across states. SERCs determine tariffs for the generation, supply, transmission, and wheeling of electricity within their states. CERC and SERC related cases are adjudicated by the Appellate Tribunal for Electricity (APTEL).

Generation is undertaken by Central, State and private GenCos. Central GenCos have the freedom to supply electricity to multiple states, whereas state GenCos are limited to their respective states. Private GenCos, commonly referred to as Independent Power Producers (IPPs), sell electricity to central GenCos, DisComs or private consumers. Central, state, and private GenCos account for 25%, 28%, 47% of total national generation [63]. Among GenCos, NTPC is the largest electricity company in India, producing 17% of national electricity. Established in 1975, NTPC is a large publicly-traded diversified conglomerate, 54% owned by the Centre [64]. While its core business is building and

CENTRAL GOVERNMENT 29 STATE GOVERNMENTS PRIVATE SECTOR		
(International, National, Interstate Matters) (Intra-State Matters)		
CONCURRENT LEGISLATIVE AUTHORITY	✓	✓
POLICY	Ministry of Power, Ministry of New and Renewable Energy (MNRE)	State Power Departments
REGULATION	Central Electricity Regulatory Commission (CERC)	State Electricity Regulatory Commissions (SERCs)
SYSTEM OPERATION	National Load Dispatch Center (NLDC), Regional Load Dispatch Centers (RLDCs)	State Load Dispatch Centers (SLDCs)
GENERATION	Central GenCos	State Generating Companies
TRANSMISSION	Central Transmission Utility	State Transmission Utilities
DISTRIBUTION		State Distribution Companies (DisComs) Dominate Distribution
POWER TRADING		Power Exchanges, Bilateral Markets
N/A		

Fig. 4. The federal political-economic structure of the Indian power sector.

operating thermal plants, it recently announced a 60 GW RE capacity target by 2032 [65].

NTPC and the Solar Energy Corporation of India (SECI), also owned by the Centre, are the largest offtakers of RE power, and referred to as “central offtakers”. Compared to NTPC, SECI (founded in 2011) is a much younger, smaller, and exclusively RE-focused company. Under MNRE’s administrative control, SECI is tasked with implementing and facilitating MNRE’s mandate across all RE sources. The core RE-related business of NTPC/SECI is power aggregation and trading, which serves a strategically important sector role. In this business model, they act as intermediate power procurers on behalf of credit-risky DisComs (see Fig. 5), with whom IPPs are wary of directly contracting with [66–68]. NTPC/SECI stage competitive reverse-bidding auctions [8,69] with IPPs and typically procure electricity through 25-year PPAs. They sell contracted power to DisComs via Power Sale Agreements (PSAs) at nominal profit of Rs 0.05–0.07/kWh (*i.e.*, trading margin) that buffers against DisCom payment delays/default [70]. To insulate themselves from market/execution risk, NTPC/SECI sign PPAs with IPPs only after DisComs first sign PSAs for the contracted power [70].

India’s distribution network is primarily (95%) managed by public state DisComs. DisComs buy power from generators and have a monopoly over distribution at regulated tariffs. Eight private DisComs also operate and mainly serve urban areas (including Delhi, Mumbai, and Kolkata). Hereafter we focus on state DisComs.

DisComs are chronically financially distressed [71]. We devote section 3 to detailing their distress. All RE stakeholders must thoroughly understand DisComs’ bleak condition for the following three reasons. First, DisComs are Generators’ primary customers. Second, DisComs are the only interface with end-consumers and therefore the cash register for the entire power sector. Third, DisComs are determiners of distributed

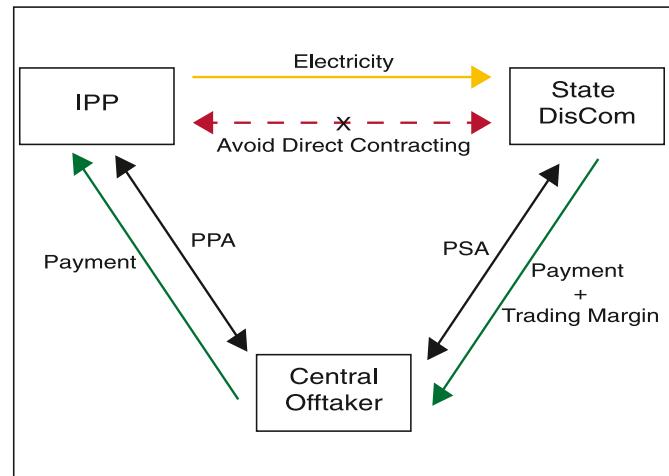


Fig. 5. Central offtaker (*i.e.*, NTPC and SECI) intermediary contracting structure in federal auctions.

RE project regulations. DisComs’ persistent financial distress threatens the viability of the entire power sector, generates major offtaker risk [72] for RE investments, and hinders distributed RE market growth.

2.3. Consumers

DisComs’ most significant consumer categories are residential, agricultural, commercial, and industrial (C&I). Consumers can also

privately procure power per the EA. C&I consumers have several options to privately procure RE power: through land-based Open Access plants (structured as captive, group-captive, or third-party projects) and rooftop PV. Open Access is a regulatory mechanism that allows a grid-connected consumer, with a load of 1 MW or more, to privately procure power. Through this mechanism, private generators, generate electricity outside the end-consumer's premises, and wheel the electricity (for a fee) to the end-consumer's premises. C&I customers have several incentives to privately procure RE electricity: lower costs by 15–40% [73], gain long-term cost commitment, satisfy mandated Renewable Portfolio Standard requirements [8,74], and meet corporate sustainability goals.

2.4. Financiers

Utility scale RE projects are typically financed with 20–30% equity and 70–80% debt [31,68]. Attracted by sector growth opportunities and asset consolidation, private equity (PE) funds and foreign institutional investors [57] have emerged as the dominant source of equity capital. At the project debt origination stage, domestic banks and Non-Banking Financial Companies are the largest financiers of debt. Operational brownfield assets are generally refinanced by public sector banks. Large institutionally backed IPPs have the advantage of refinancing debt at comparatively lower rates in foreign bond markets.

2.5. Legal system

India has one of the world's weakest and slowest legal systems that is characterized by an extremely limited capacity and poor contract enforceability [75]. On average, it takes nearly four years to enforce a contract in India, compared to one year in the U.S. (Fig. 6) [76]. Furthermore, routine corruption is rampant across the government bureaucracy and the judicial system [77].

As a remedy for the dysfunctional legal system, an extra-judicial system [60] has been established to resolve disputes in the power sector. EA authorizes CERC and SERCs to adjudicate disputes relating to interstate matters and intra-state matters, respectively. CERC is empowered to adjudicate upon disputes involving central GenCos or IPPs involved in interstate generation or transmission. SERCs are authorized to adjudicate upon disputes between licensees and generating companies. Both CERC and the SERCs also reserve the power to refer any dispute to arbitration. APTEL has *suo motu* jurisdiction to examine the validity of any CERC or SERC order and the power to entertain appeals against decisions of CERC and SERCs [60]. The relevant High Court of each state adjudicates on questions of law for parties

aggrieved by the order of any electricity regulatory commission. Appeals against APTEL's decisions, however, must be filed before the Indian Supreme Court.

3. DisCom financial distress: the power sector's weakest link

We will now detail the financial distress of the DisComs, explain its root causes and how it creates problems for RE IPPs.

3.1. DisComs are chronically indebted

India's DisComs are in a state of continuous financial loss [71]. Since 2003, DisComs' average cost per kWh³ billed has been consistently higher than average revenue per kWh billed [79–81]. Currently, on average DisComs lose Rs 0.5–1.0/kWh delivered [82]. Their large operational losses create constant cash flow problems and insolvency challenges. They have hobbled through a decade-long liquidity crunch, with continuously larger payables than receivables. Fig. 7a shows their payables and receivables days, which have been consistently several times longer than contractual payment cycles with GenCos (30–60 days) and consumers (25 days) [83]. DisComs have dealt with a constant lack of cash by taking working capital loans, relying on state subsidies (16% of DisCom revenues [84]), and delaying payments to GenCos until receivables come in. Payment delays to GenCos range from 2 to 13 months, generating illiquidity issues across the power sector. Late payment dues to GenCos—partially captured on the PRAAPTI portal [85]—have consistently grown (Fig. 7b) [83]. Aggregate PRAAPTI dues (capturing data from sub-35% of total GenCos) stand at \$12 bn (of 9/21); total dues are likely severalfold larger [83].

From a balance sheet perspective, DisComs have a large negative net worth of \$11 bn (FY19) with gross debt over \$69 bn (FY20) [84]. They are feebly positioned to service their high debt load, with a leverage ratio (gross debt/OPBDITA⁴) of 24× and interest coverage ratio of 0.4× [84].

DisComs' remain financially fragile despite receiving 3 massive Centre bailouts in the last 8 years (See 3.3). Bailouts have mostly comprised various loan write-offs or concessional loan refinancing. In the 2016 UDAY bailout [81], states took over DisCom debt by issuing \$32 bn in bonds [84]. UDAY debt deleveraging initially reduced annual book losses (Fig. 7a) and non-state government loans (Fig. 7b) between FY15–FY17 [84]. However, continuous operational losses and Covid-19 demand reduction have caused book losses and gross debt to surpass pre-UDAY levels.

3.2. Root causes of DisComs' financial distress

DisComs chronically lose money because their average cost per kWh billed has been consistently higher than average revenue per kWh billed since 2003. This consistent unprofitability has four root causes:

1. Politicized low-tariffs unreflective of costs
2. High operational losses (AT&C losses)
3. Unreliable and inadequate state government subsidies
4. Inflexible and expensive procurement costs

We will now explain these causes, depicted in Fig. 8.

³ See Ref. [78] for Government of India methodology of calculating DisCom Average Cost of Supply ("ACS"; in Rs/kWh) and Average Realisable Revenue ("ARR"; in Rs/kWh). Ostensibly, DisCom "ACS-ARR Gap" data is to be used in determination of DisCom consumer tariffs.

⁴ Operating Profit Before Depreciation, Interest, Taxes and Amortisation (OPBDITA).

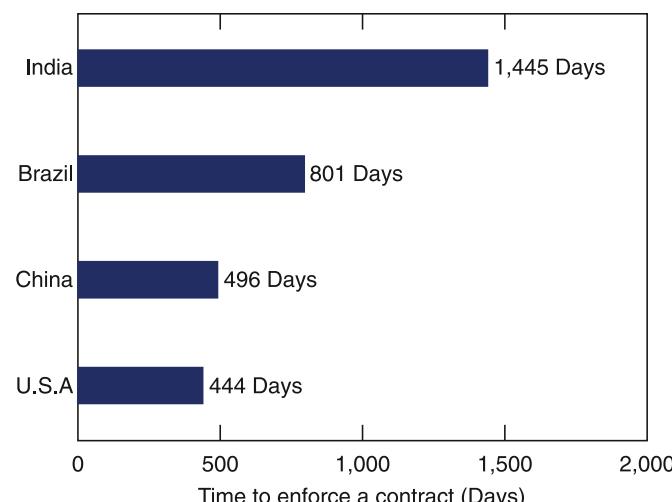


Fig. 6. Average days to enforce a contract for select countries in 2019. Data from the World Bank [76].

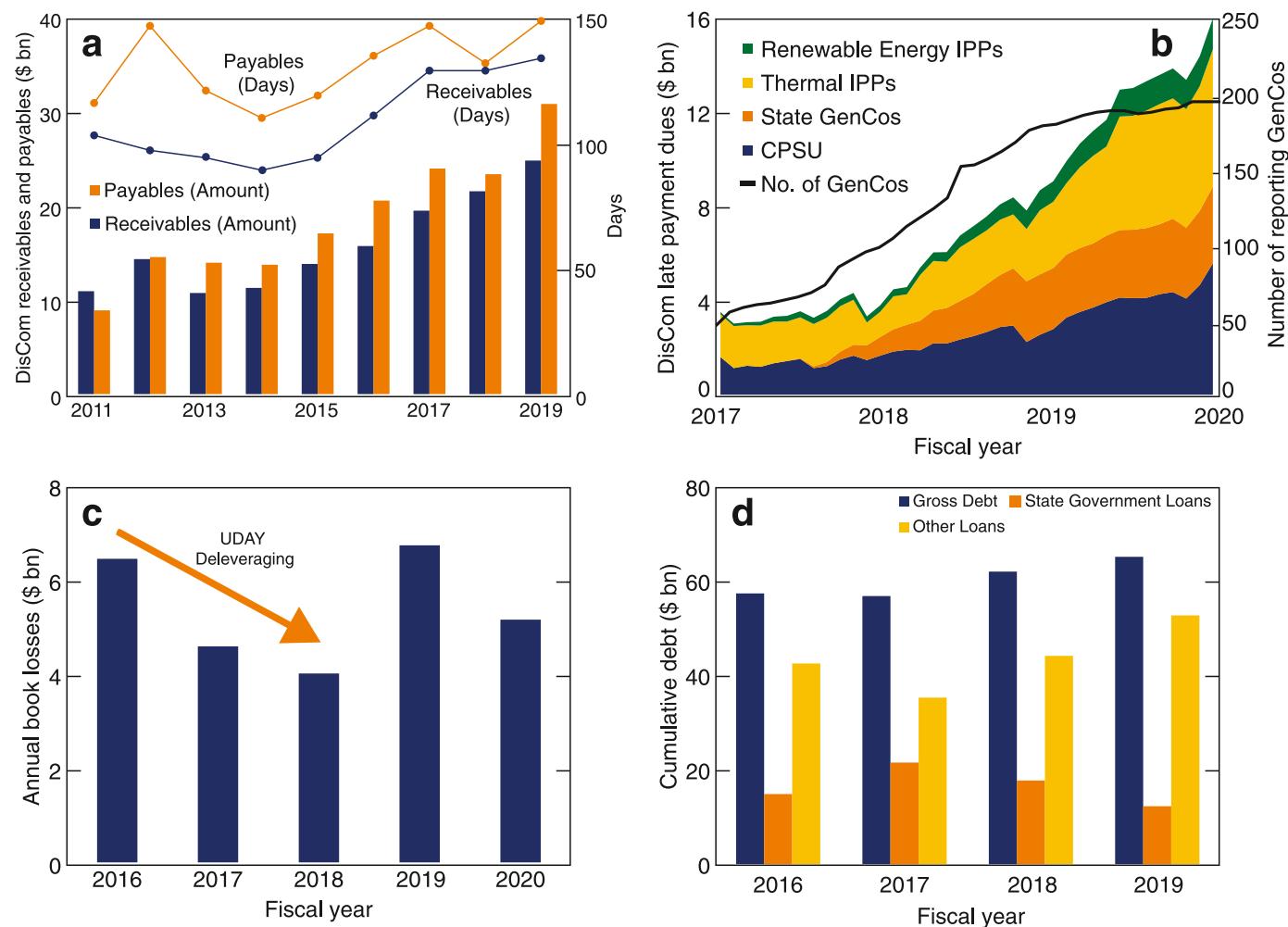


Fig. 7. Trends of all-India-level DisCom losses by a) annual book losses b) gross debt c) receivables and payables d) late payment dues to participating number of Generating Companies (GenCos) in the PRAAPTI portal. Fig. a/b and c/d data courtesy of ICRA [84] and CSEP [83], respectively.

3.2.1. Politicized low-tariffs unreflective of costs

DisComs charge certain consumers artificially low tariffs unreflective of costs. This negatively impacts their revenues and profitability. Low tariffs are set through a highly politicized and institutionalised process that prevents DisComs from simply raising tariffs. Each FY, DisComs calculate appropriate tariffs for each consumer category based off projected distribution sales and costs. Calculated tariffs are presented to the state government and SERC for approval. Approved tariffs, however, are substantially lower than those proposed for important voting blocks: agricultural, residential, below-poverty line households, and religious entities [29,82]. Ostensibly, this is done for social welfare. Practically, politicians of all parties co-opt cheap power to curry favour with crucial voting blocks [29,82]. State governments later announce a lump-sum subsidy (“subsidy booked”) to compensate DisComs for tariff markdowns. In practice, the “subsidy realized” is much lower than booked and delivered very late [82,86]. Once set, tariffs are also infrequently revised, and have not kept pace with inflation over the last decade [14,29].

Tariffs for different consumer groups vary widely, with large variations across states. Representative tariffs are Rs 0–1/kWh for agricultural; Rs 4–6/kWh for residential; Rs 7.5–10/kWh for C&I [63]. Providing free electricity to farmers is an institutionalised political handout that has been occurring for decades.

Of the top 20 industrialised Asian nations, India is the only one to charge C&I consumers substantially higher tariffs than residential consumers [63]. This “cross-subsidy” (Fig. 9)—from C&I to agricultural and

residential consumers—is significantly large and implemented to compensate for revenue lost to subsidies. Across India, C&I consumes 37% of total electricity but pays 49% of total revenue; agriculture consumes 22% of total electricity but pays less than 4% of total revenue⁵ [63].

3.2.2. High operational losses (high AT&C losses)

High operational losses reduce DisCom cash flows. Losses are quantified by the *Aggregate technical and commercial losses* (“AT&C”) [88]:

$$AT\&C\ Losses = [1 - (Billing\ Efficiency \times Collection\ Efficiency)] \times 100, \text{ where.}$$

Billing Efficiency = Total energy billed to consumers (kWh) / total energy supplied to distribution area (kWh) over time window.

Collection Efficiency = Consumer revenue collected (Rs) / billed amount (Rs).

Despite several bailout-linked reforms, average DisCom AT&C losses remain high at 20%. Fig. 10 shows these losses are well above the UDAY

⁵ Provision of free power to millions of agricultural consumers is a major driver behind India's inefficient irrigation practices, and the modern practice of large farmers growing water-intensive cash crops (e.g., rice and sugarcane) in water-scarce areas. Surprisingly, it also doesn't actually help most farmers [87] since 56% of rural homes have no land, mainly working as farm laborers, and less than 10% own any irrigation equipment.

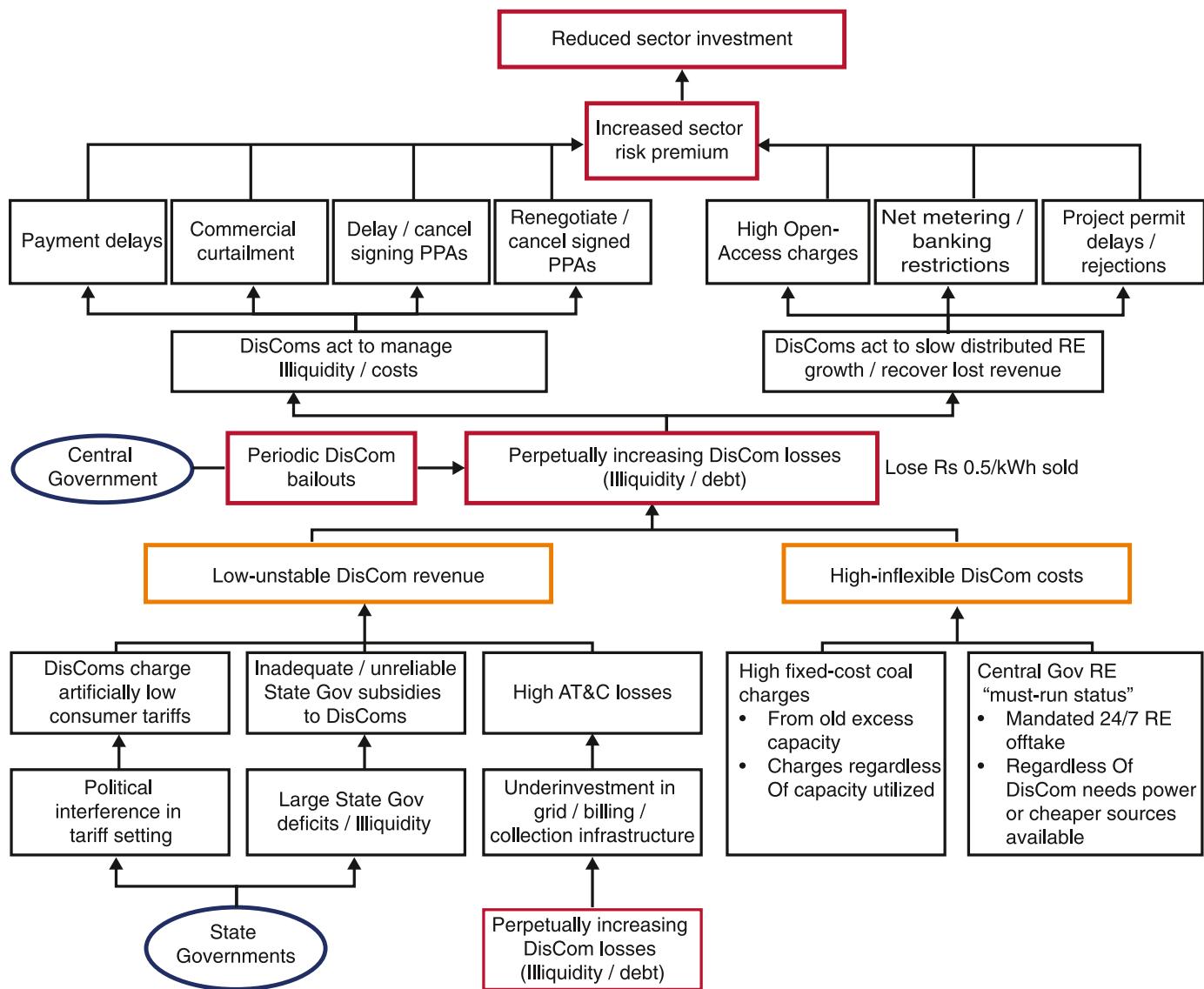


Fig. 8. Root causes of DisComs' financial distress.

15% target by 2019, and 6% losses of average private DisComs [84].

High state DisCom losses derive from poor grid infrastructure, theft, corruption, and billing/collection inefficiencies [29,71,82,86]. In comparison, low-loss private DisComs benefit from superior operational management and serving primarily urban areas with low exposure to agricultural consumers [82,84]. Notably, state DisCom AT&C losses

vary widely by state. Losses range from sub-15% in more-developed (and often populous) states (e.g. 12% in Gujarat) to above-30% in less developed states (e.g., 38% and 44% in Uttar Pradesh and Nagaland, respectively) [81].

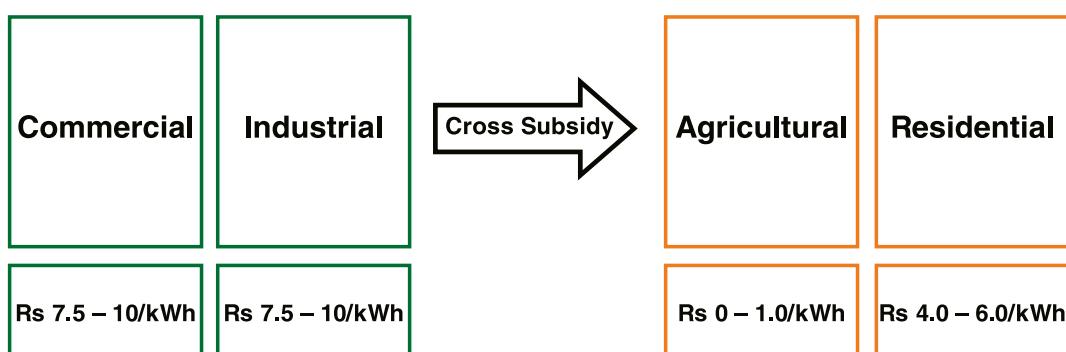


Fig. 9. Schematic of "cross-subsidy" from commercial and industrial DisCom-consumers to agricultural and residential DisCom-consumers.

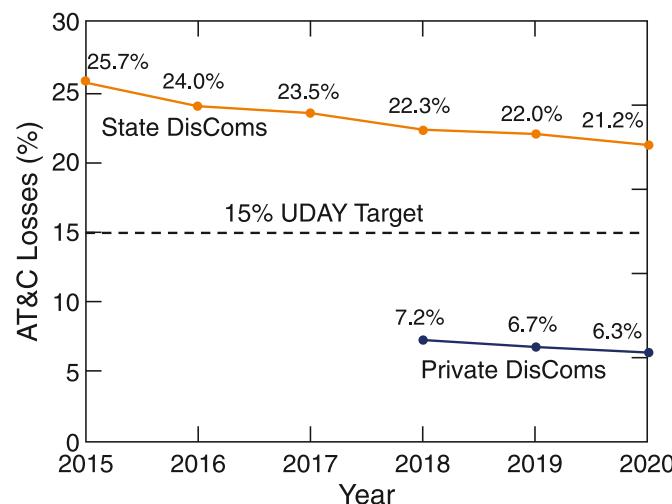


Fig. 10. All-India-level DisCom annual aggregate and technical (AT&C) losses relative to losses of select private DisComs and UDAY scheme's 15% AT&C target in 2019. Private DisCom losses shown are an average of losses from Tata Power (Delhi), Torrent Power (Ahmedabad and Gandhinagar), Torrent Power (Surat) and CESC Kolkata and Howrah). Data courtesy of ICRA [84].

3.2.3. Unreliable and inadequate state-government subsidies

Promised subsidies from states—estimated to be 16% of DisCom revenues in FY22 [84]—are often late or never delivered, resulting in expanded losses on DisCom books. Ballooning state deficits further jeopardize already undependable state-government support [86].

3.2.4. Inflexible and expensive procurement costs

Across India, 90% of electricity is contracted through long-term bilateral PPAs. Presently the spot market is very thin and immature; no strong time-of-day pricing mechanism exists as in other developed countries. Power procurement costs, primarily via PPAs, constitute 75% of DisComs' total structure [82]. DisComs have inflexible, expensive power procurements costs that undermine their operating financials. The primary sources of these inflexible, expensive procurement costs are fixed-charges (i.e., capacity-charges) from coal capacity, and the “must-run” RE mandate.

DisComs are burdened by legacy coal PPAs that contain fixed-cost charges⁶ [89] they must pay regardless of their coal power consumption volume (i.e., even if no power is drawn from a plant). These fixed-charges are substantial. Out of the Rs 4/kWh characteristic coal tariff DisComs pay coal generators, fixed-charges represent nearly 50% of the total cost [90]. Fixed charges have become increasingly burdensome as coal fleet Plant Load Factors (PLFs) have rapidly fallen. Between FY10–FY20, the coal fleet's national average PLF has fallen from 78% to a historic low of 55% [14]. Decreasing coal PLFs have resulted from one, the government overinvesting in new coal capacity (between 2011 and 2016) due to overestimating future power demand in the early 2010s, and two, RE gaining share due to its priority dispatch and increasingly competitive costs [14].

Owing to overbuilt coal capacity, India now has a temporary surplus of excess gross generation capacity. Firm generation capacity (excluding gas capacity with uncertain supply and excluding intermittent RE capacity) stands at 259 GW (of Nov 30, 2020), compared to peak demand of 183 GW (which peaked on Dec 30, 2020) [91]. This capacity surplus is expected to last for the next four to five years [9].

⁶ In the power sector's “cost-plus” framework regulatory set fixed-charges are designed to adequately account for plant depreciation, operation and maintenance expenses, loan interest and finance charges, interest on working capital, taxes, and return on equity [89].

Moving forward there is no clear path for DisComs to stop paying expensive fixed charges to coal generators. Legally, it is not straightforward to renegotiate coal PPAs as some sector analysts have advocated [86,92,93]. Moreover, presently it is not techno-commercially viable to blanketly retire coal plants. It is true that newer RE tariffs are lower than those of many coal plants—particularly those far away from coal mines that bear high coal transportation costs—and India's coal fleet contains \$100+ bn of stranded assets [29]. The current grid, however, needs “excess” coal capacity to maintain grid reliability when intermittent RE power plants stop generating. For example, coal generation is absolutely essential during India's evening peak, when RE contributes only a few percent of total generation on many days of the year [91]. Furthermore, coal plants can generate substantially more energy/MW capacity than RE, given their higher PLFs. Coal plants are designed to operate at a PLF (75%) 3 times greater than observed Indian PV and wind plants in India. Ideally, under India's present cost-plus [89] system, the fixed costs of maintaining “excess” coal capacity should be borne by consumers. This, however, is unlikely to happen given politicized low tariffs. Transition to more flexible power system would allow DisComs more flexibility to manage their system costs and meet environmental regulations. Such a system could incorporate widespread spot market procurement, strong time-of-day pricing, and a smart grid allowing for great coordination across states and regions [91]. It is unclear how and when a transition to such a system would occur.

CERC's RE “must-run” mandate also contributes to inflexible, high DisCom costs. The mandate forces DisComs, when scheduling power amongst all possible generators, to first buy intermittent RE power, regardless of RE tariffs relative to other available sources or DisComs' needs. This is particularly problematic for one, older RE plants [92] sell DisComs at tariffs (Rs 8–12/kWh) [29] far greater than the current average coal tariffs (Rs 4/kWh) and two, certain wind plants produce peak power when demand is low.

DisComs are therefore trapped in a situation where they must pay fixed coal charges, regardless of their coal generation consumption, and are forced to buy all the RE generated, regardless of RE offtake costs relative to other sources, RE intermittency problems, and DisCom real-time power needs.

3.3. Prior DisCom reforms have failed

Major attempts to reform the distribution sector have failed to make meaningful sustained impact. The sector has received three monumental Centre bailouts in the last nine years: 2012 Financial Rescue Package [80] (\$21 bn debt restructuring), 2015 UDAY scheme (\$32+ bn debt restructuring) [81], Covid-19/Atmanirbhar stimulus [84] bills (\$120 bn commitment to energy sector, including \$17 bn DisCom emergency liquidity support). Each bailout has been a response to a DisCom liquidity crisis that threatened the entire power sector⁷ and included a mix of cash-injections and operational improvement milestone-based subsidies.

Past bailouts and other reforms have failed because they have been limited technocratic solutions to DisCom problems that are inherently political and cultural.

3.3.1. Bailouts have been weak technocratic solutions

Technocratic bailouts have temporarily fixed liquidity issues but not the root political and cultural causes of dysfunction. Technocratic milestone driven subsidy components of the bailouts were based on unrealistic financial models and operational metrics with little likelihood for success [82].

⁷ In 2012, DisCom leverage was so high it threatened not only the power sector, but also contagion across the entire Indian financial sector [80].

3.3.2. Political problems prevent reform

The Centre lacks constitutional authority to impose unilateral change on state-owned DisComs, including strong consequences for reform measure non-compliance. State politicians understand the problems but are averse to implement strong reforms that adversely affect key voting blocks. This is further exacerbated by the fact that State politicians don't have accountability for commercial losses, which result in frequent bailouts creating moral hazard.

3.3.3. Ingrained cultural attitudes prevent reform

Ingrained cultural beliefs make it politically challenging to structurally reform the power system, would threaten existing benefits to vested interests. Decades of political meddling and handouts have resulted in a cultural belief in the citizenry that power access is a fundamental right that cannot be restricted because of the inability to pay. This is further augmented by beliefs that socially minded governmental bureaucratic control is beneficial for society, and better than profit-driven, private management. Furthermore, maintaining DisCom employment is valued above employee accountability and efficiency.

4. Strategic sector risks and mitigation strategies

We will now discuss the following nine strategic sector investment risks and corresponding mitigation strategies:

1. Project development risk
2. Offtaker risk
3. Stranded asset risk
4. Volume risk
5. Curtailment risk
6. Regulatory risk
7. Inflation risk
8. Exchange rate risk
9. Tail risk

A timeline of when each risk threatens a RE project in its lifecycle is presented in [Fig. 11](#). We emphasize that of the nine risks, offtaker risk is the dominant sector risk that most concerns investors [\[27,31,72,94\]](#).

4.1. Project development risk

4.1.1. Description

Land-based greenfield RE projects face significant project development risks during the 18–24 months process to commission an RE plant. These risks include time overruns, cost overruns and outright failure. Key bottlenecks include land acquisition, securing necessary financing and permits, obtaining grid connectivity, and plant construction. Legal and cultural idiosyncrasies [\[95\]](#) make land acquisition the most significant bottleneck. Land procurement for wind projects is particularly difficult and a major reason why wind capacity additions have fallen in recent years. This is because wind resources are often located far away from major population centers/transmission networks. Furthermore, 91% of national wind potential [\[96\]](#) is concentrated in just six states (Gujarat, Rajasthan, Karnataka, Maharashtra, Andhra Pradesh, and Tamil Nadu). In absence of major reforms, the aforementioned risks will likely compound with time [\[8,97\]](#).

4.1.2. Mitigation strategies

Only invest in operational assets or proven developers: Investors can avoid development risks altogether by investing exclusively in brown-field operational assets. Those who take on development risk for higher returns can minimize risks by working with developer management teams with a proven track record of executing projects.

Avoid wind projects: Many IPPs now exclusively develop PV projects to avoid wind projects' relatively higher development, volume, curtailment and offtaker risks). Sector CEOs expect [\[98\]](#) 50 GW PV vs 10

GW wind capacity additions over the next 5 years.

Solar parks: Central and state offtaker “solar park” projects [\[13\]](#) have low development risk. Solar parks are large, concentrated zones for large (1–30 GW) PV projects and offer the largest scale PPAs. They are designed to reduce generation costs through economies of scale and low development risk. Projects come with guaranteed land, transmission, and permitting rights. The government agency that awards solar park PPAs (e.g., SECI) plans, operates, and maintains the park. The agency identifies the site, obtains land access and statutory clearances, designs the plan to share development costs among IPPs, and provides all infrastructure services including water, transmission, roads, and drainage. Solar park projects offer IPPs lower risk and returns. Their competitive tariffs are the lowest in the market, and their land/transmission rights leases are higher than private market rates, lowering project equity internal rate of return (EIRR) [\[68\]](#).

Private land procurement strategies: IPPs can successfully procure land by targeting barren farmland, leasing land instead of buying, or outsourcing procurement to professional land aggregators.

4.2. Offtaker risk

4.2.1. Description

The most significant risk to Indian RE investments is offtaker risk [\[27,31,72,94\]](#), where an offtaker breaches its contractual obligations. There are three types of offtaker risk:

1. PPA signing delay/cancellation
2. Payment delay
3. PPA renegotiation/cancellation

DisComs are incentivized to pursue these tactics to reduce their financial distress in an environment of rapidly falling RE tariffs. Furthermore, they are undeterred from routinely breaching contracts because of poor legal contract enforceability.

We will now explain each type of offtaker risk and then discuss risk mitigation strategies that collectively address all three types.

4.2.2. PPA signing delay/cancellation

DisComs frequently delay signing PPAs or cancel after awarding state PPA auction Letter of Awards [\[29\]](#). In NTPC/SECI auctions, DisComs similarly delay or withdraw commitments to sign PSAs [\[99\]](#). Similar risks exist in the C&I/residential markets. With rapidly falling tariffs, offtakers resort to these tactics to avoid getting locked into procuring expensive electricity from plants installed just a few years back. PPA signing delay/cancellation occurs across most states—including India's most credible Gujarat GUVNL DisComs, illustrated in the following case. In October 2020, GUVNL awarded 700 MW of auctioned capacity, at Rs 2.78/kWh, for the Dholera solar park [\[100\]](#). Two months later, GUVNL auctioned 450 MW of PV capacity at an all-India record-low of Rs 1.99/kWh [\[101\]](#). This price discovery led GUVNL to petition its state SERC to retender the 700 MW of Dholera capacity, claiming its high tariffs would adversely burden DisComs and consumers. The regulator promptly approved GUVNL's request “for the public good” [\[102\]](#), leaving winning IPPs as collateral damage [\[103\]](#) GUVNL previously cancelled auctioned capacity in 2018 (450 MW) and 2019 (700 MW), citing high tariffs [\[102\]](#). These incidents in “bankable” Gujarat demonstrate just how pervasive PPA renegotiation/cancellation risk is.

4.2.3. Payment delay risk

Payment delay risk is the dominant and most constant risk to RE projects. It is the risk that contracted electricity will not be paid within contractual time or paid in full. Cash-strapped DisComs have adopted delaying payments as a business strategy to manage their cash flows and minimize taking on expensive working capital loans. Contractual payment time is typically 30–60 days from the time offtakers receive an invoice. However, RE generators face average DisCom payment delays

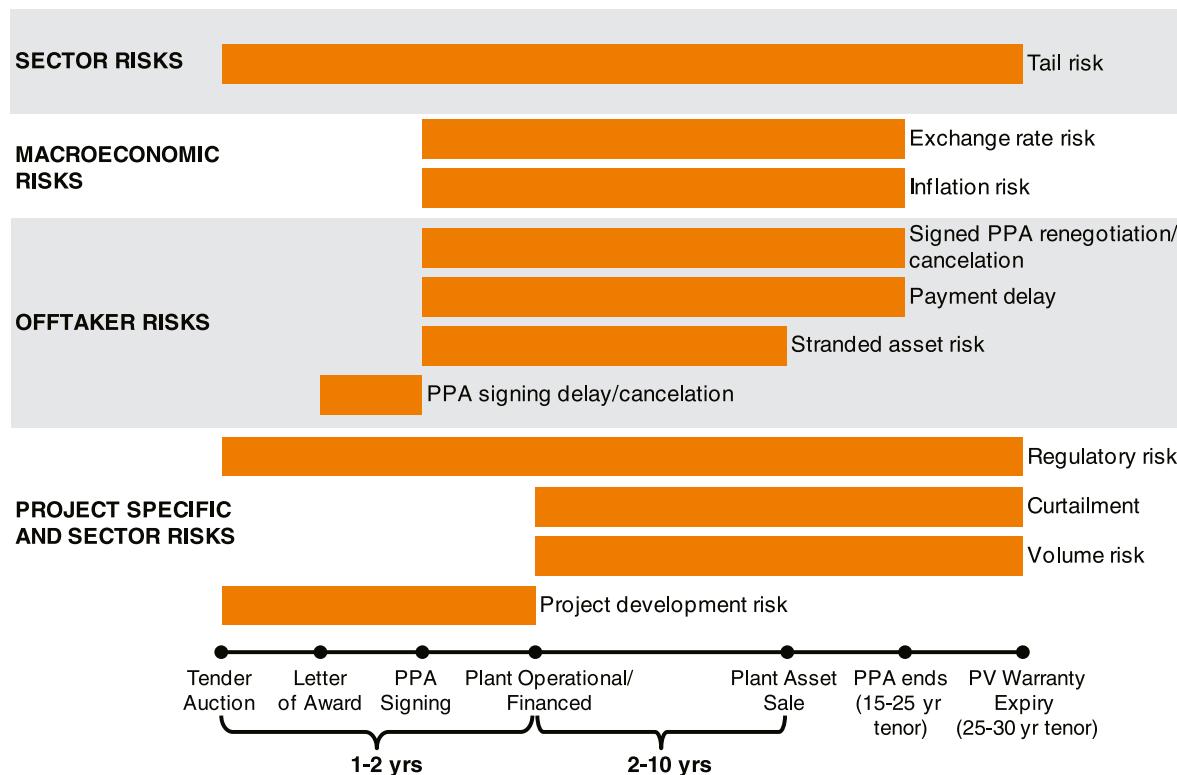


Fig. 11. Timeline of strategic investment risks over an RE project's life.

of 11 months [28]. Payment days vary wildly among offtakers and change with time. Fig. 12 shows recent average payment days for solar IPPs, as reported by ICRA [104]. Payment days range from 30 days (Gujarat and NTPC) to 540 days (Andhra Pradesh and Tamil Nadu).

Payment delay hurts generators in multiple ways. First, it reduces a project's realized EIRR. Payment delays create a liquidity strain for generators, limiting their ability to make timely debt payments and forces them to take expensive working capital loans. In such a scenario, existing lenders, weary of their exposure to default, are reluctant to provide fresh capital. New lenders are hesitant to take a secondary position on highly uncertain and tainted DisCom receivables. Second, for large IPPs (>2 GW portfolios) that utilize significant project cash accrual for growth, payment delays jeopardize competitive positioning in new auctions and successful implementation of awarded projects. Third, an established culture of substantial payment delay increases the sector risk

premium, raising the cost of capital for new projects [27].

Fig. 13a illustrates how payment delays can significantly lower realized EIRR for a modeled utility-scale PV project relative to expectations [68]. The model assumes a base case expected EIRR, modifies one input variable at a time and assumes IPPs take working capital loans to compensate for cash flow shortfalls. The figure shows how the EIRR reduction depends on average payment delay time (i.e., number of months of receivables for IPPs) and the number of years the delay persists over the project PPA life (shown as different figure curves). In the extreme case of a 12-month payment delay occurring over the entire PPA life, the EIRR is reduced by around 500 basis points (bp). Such a scenario could easily occur with weak DisComs in Tamil Nadu or Andhra Pradesh.

The conventional protection against payment delays, PPA letters of credit (LCs) [105], are ineffective with DisComs (but effective with C&I offtakers). DisCom PPAs require parties to maintain revolving LCs (covering a two-month payment cycle for one year) but are rarely created in practice. PPAs specify which party—the DisCom or IPP—has to create the LCs and pay the associated opening fees with a bank. In instances where DisComs must open LCs, they rarely do so. In instances when IPP must open LCs, they don't do so to avoid paying continuous LC related fees. Given this dysfunction, investors entirely discount LC provisions when valuing DisCom PPA cash flows in M&A transactions.

4.2.4. PPA renegotiation/cancellation

PPA renegotiation/cancellation is the risk that an offtaker will renegotiate or cancel signed PPAs. In such scenarios, IPPs risk debt default, negative equity returns, protracted legal fees, and stranded assets.

We now discuss the infamous case of Andhra Pradesh (AP) to illustrate this risk. In 2019, AP's newly elected Chief Minister unilaterally renegotiated billions of dollars' worth of PPAs [33]. He alleged corrupt awarding of the PPAs under the previous government and questionably blamed [29,33] the older high-cost PPAs for the huge losses of AP DisComs [107]. In reality newer project tariffs were lower due to recent technological advancements, economies of scale and contracting via

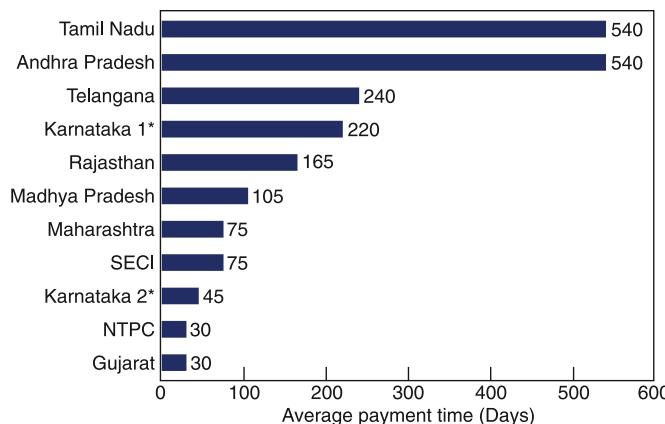


Fig. 12. Recent offtaker average payment days to solar IPPs. Karnataka 1* and Karnataka 2* DisComs, are BESCOM/MESCOM/CESCOM and HESCOM/GESCOM, respectively. Data courtesy of ICRA.

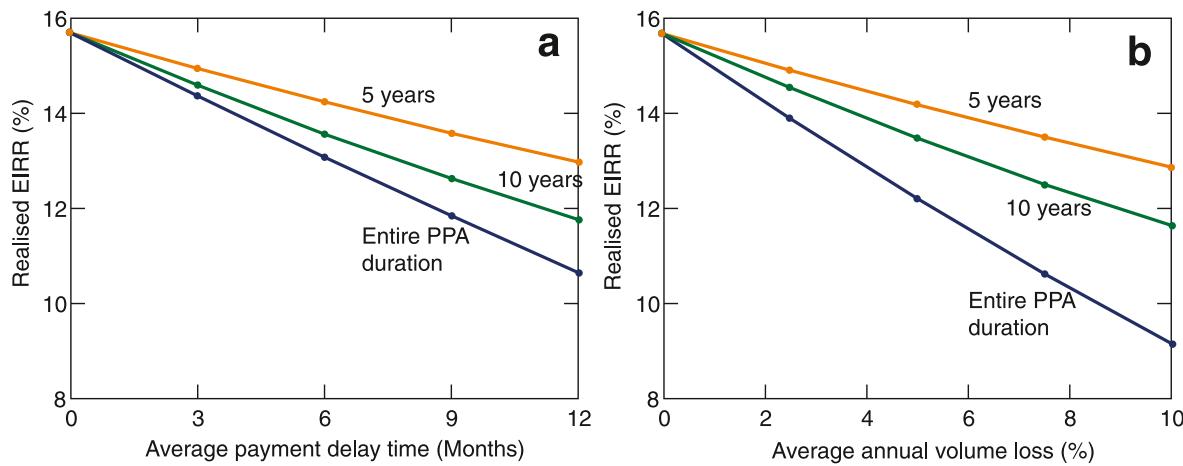


Fig. 13. Realized EIRR sensitivity of a modeled utility-scale PV project to a) payment delay b) volume loss. In each plot, the different curves correspond to the number of years payment delay or volume loss occurs over the project PPA life. Data courtesy of CEEW and the IEA [68].

reverse-auctions. Furthermore AP utilities had been among India's most underperforming and indebted for decades [61,80,106].

AP DisComs initiated several unlawful actions including retrospectively cutting tariffs from old PPAs by 55% to match the most recent lowest levels ever recorded in India, threatening to cancel PPAs if new tariffs were not accepted, issuing notices to recover past payments for projects with higher tariffs, practically stopping all payments to RE IPPs, challenging RE's must-run status, and cancelling over 20 under-construction RE projects [29]. AP's ad-hoc actions stunned IPPs and global investors for several reasons. Firstly, 10% of India's total RE capacity [33,34] was jeopardized in AP, previously India's most RE investor-friendly state. Secondly, AP's 55% downward tariff revisions threatened IPPs with debt default and negative equity returns [33]. Thirdly, for many IPPs with disproportionate portfolio exposure to AP the cash-flow hits would cause major stress at the holding-company level [33].

IPPs, who had stopped receiving payments from AP DisComs, legally challenged the AP's actions. They succeeded in getting interim payments at the revised reduced tariff rates but subsequently suffered irregularly excessive curtailment from the state grid operator [108]. The case is still undecided in courts after two years of legal battles. This AP case study powerfully illustrates the fragility of rule of law, states' autonomy in distribution and the election-dependent, extreme regulatory volatility investors can face in the largest democracy in the world.

4.2.4.1. Mitigation strategies. Portfolio diversification:

Diversifying an asset portfolio across offtakers reduces idiosyncratic offtaker risk.

Contract with strong offtakers: Signing/buying PPAs with strong offtakers, who are financially strong enough to meet their payment obligations, is the dominant strategy to minimize payment risk. The strongest offtakers in the utility-scale market are SECI, NTPC and Gujarat DisComs, whereas A+ rated Indian and multinational corporations are the strongest offtakers for the C&I market. Section 5 provides a detailed discussion on offtaker strength analysis.

4.3. Stranded asset risk

4.3.1. Description

Stranded RE assets are operational assets that suffer premature devaluations or write-downs due to cash flow losses and lack of buyers. Potential buyers may avoid the asset out of fear of offtaker risk or curtailment (4.5). Such situations leave investors stranded with no ability to recycle invested capital into more lucrative investments.

4.3.2. Mitigation strategies

Contract with strong offtakers: Contracting with offtakers with no history of payment delay or PPA renegotiation reduces stranded asset risk.

Avoid high-tariff PPAs assets: Many investors avoid acquiring older RE assets with higher tariffs as they are more likely to face stranded asset risk. Additionally, IPPs and investors mitigate this risk by selling older assets after a few years—quickly unlocking their capital and transferring asset risk to buyers. Multiple investors interviewed stated that prior to reverse auctions (2017), they would have readily acquired RE assets with PPA tariffs between 7.0 and 10 Rs/kWh, but in 2021 they would not consider buying assets with tariffs above 4.0 Rs/kWh.

4.4. Volume risk

4.4.1. Description

Plant generation volume loss, relative to its projected generation, can occur due to inaccurate initial assumptions about weather and hardware generation efficiency over time. Hardware can perform sub-optimally due to degradation and sub-optimal cleaning from poor practices or water scarcity [109]. Wind projects have higher weather resource unpredictability and correspondingly higher risk premiums than solar projects [72].

RE plants are generally financed assuming a statistical base-case *P-50* generation forecast, where a plant has a 50% chance of generating the forecasted amount. Across geographies, RE plant generation is often less than *P-50* levels [110]. Utility-scale PV plants in the U.S. (with better data than India), underperform their *P-50* estimates by 6.3%, even after adjusting for unanticipated weather changes [110]. This means that the actual generation is closer to *P-90* levels. For equity investors, who receive cash flows only after lenders and tax equity investors have been paid, systematic generation underperformance to *P-90* levels could cut cash yields by 50% during the plant's life. Unaddressed, systemic generation underperformance can significantly undermine realized IRRs.

Fig. 13b illustrates the damaging impact of volume loss on realized EIRR for a modeled utility-scale PV project [68]. The model treats volume loss as a constant-percentage annual loss of generation during a specific time period (shown as different curves). Annual volume loss of 7.5% over the PPA life typically reduces the EIRR by around 500 bp. Such a scenario could occur if plant PV modules do not have the technology to protect against “light- and elevated-temperature-induced degradation” (LeTID), which can reduce generation by up to 16% over time [111].

We note that ensuring reliable and affordable water procurement for

module cleaning is a growing challenge for PV plants, which are often geographically concentrated in dry water-stressed areas. Module soiling can lead to generation losses of 3–6% [112]. Cleaning twice a month can reduce these losses to 1% but requires extensive water use (0.1 m³/MWh) [112]. 94% of India's PV capacity is exposed to medium-high level of water stress—exposing plants to water scarcity, sudden cost increases, and conflicts with other users [112]. In 2018, a sharp increase in demand led Karnataka to increase the water tariff for industrial users 100 × [112]. Such drastic and unexpected increases can significantly hurt project economics as cleaning accounts for 14–35% of total O&M cost [112]. India's growing water scarcity [109] will magnify water risks with time.

4.4.2. Mitigation strategies

Thorough due diligence: Whether developing projects or acquiring operational assets, thorough due diligence on factors influencing plant generation can reduce volume risk. Variables to assess include hardware manufacturer bankability, hardware technology degradation rates and warranties, hardware condition, area water stress, and historic/recent plant area weather conditions.

Experienced O&M teams: Hiring experienced O&M teams with rigorous metrics on performance, service availability, and response time will further limit potential cash-flow losses [110].

Water management strategies: Robotic cleaning and PV modules with anti-soiling coatings can mitigate water needs for module cleaning. Compared to manual cleaning, robotic cleaning can increase generation by 1–2%, and has a payback period of 2–3 years [112].

4.5. Curtailment risk

4.5.1. Description

Curtailment is an involuntary reduction in a generator's output due to the grid operator restricting electricity delivery from the generator to the grid. Curtailment irrecoverably impairs project cash-flow and undermines the generator's timely ability to service debt. We note curtailment is often classified as a form of offtaker or volume risk.

Curtailment occurs for technical or commercial reasons. Technical curtailment can occur due to transmission congestion, lack of transmission access, excess generation during low-demand periods, and frequency requirements [56,113]. Renewable generation, compared to thermal power, is more susceptible to technical curtailment because it can be more easily switched off and is highly intermittent. Curtailment can alternatively be commercially motivated to reduce DisCom costs (implemented via DisCom collusion with state grid operators). There is increasing evidence of commercial curtailment being selectively enforced on older high tariff RE sources, done under the guise of maintaining grid stability to circumvent the RE must-run status [114].

Curtailment risk is rising as increasing amounts of cheaper RE capacity is added to India's grid that is not growing fast enough [26] to accommodate it. Fig. 14 shows the concerning slowdown in annual growth of net transmission capacity: from 9% in 2015 to 2.6% in 2019 [29]. The slowdown has been attributed to underfunding and project delays [115]. Various Centre initiatives [116] to increase inter-state and intra-state transmission and distribution capacity to accommodate growing RE (including the Green Energy Corridor) have been major disappointments [29,115].

4.5.2. Mitigation strategies

Avoiding high-risk states: Curtailment risk depends on a complex set of interdependent variables—making it difficult to accurately quantify. Investors, however, can partially mitigate it by avoiding states with risk factors including anticipated low future power demand, high grid congestion, high RE penetration, history of frequent curtailment and weak DisComs. In mergers and acquisitions (M&A) due diligence, investors rely on detailed load flow analyses [117,118] to assess curtailment probabilities.

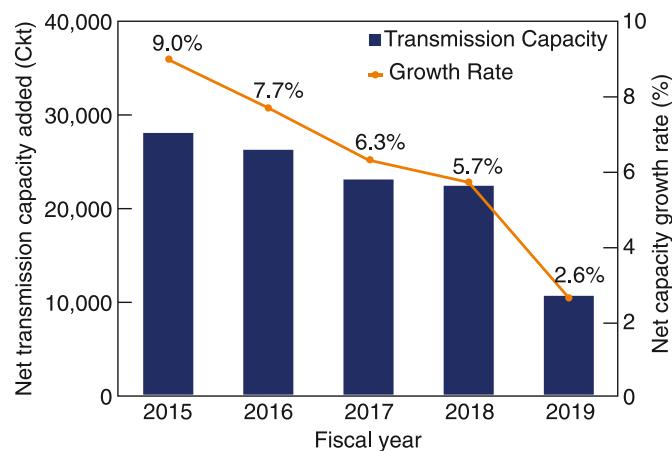


Fig. 14. India's annual power transmission capacity additions and cumulative growth rate. Data courtesy of CERC and IEEFA [29].

Avoid wind assets: Compared to PV assets, wind assets are more vulnerable to curtailment because of their higher seasonal/diurnal generation variability. During high wind season, curtailment is common due to oversupply/grid congestion.

Avoid high-tariff RE assets: Higher tariff RE assets are more likely to experience commercial curtailment and payment delays.

PPA protection: Recent SECI/NTPC PPAs have curtailment compensation clauses that benefit generators on a DisCom “back-to-back” basis. The amount of electricity curtailed, for reasons except transmission unavailability or grid security issues, is compensated at half the contracted tariff price. The majority of existing RE PPAs, however, do not stipulate curtailment reimbursement [14].

M&A deferred payouts: In M&A transactions, buyers generally have more conservative views about future asset generation/curtailment than sellers. Buyers can protect themselves by paying an agreed-upon base acquisition price and make subsequent deferred compensation payments (typically over 2–3 years) linked to realized cash-flows.

4.6. Regulatory risk

4.6.1. Description

Unexpected regulatory changes-in-law can detrimentally impact expected investor returns. Recent major examples of such changes-in-law include: The Goods-and-Service-Tax (GST) [119], 40% customs duty on imported PV modules [120], and new Open Access charges [73].

4.6.2. Mitigation strategies

PPA change-in-law clauses: Such clauses stipulate that if a new law is enacted after a PPA is signed, the unanticipated costs incurred by an IPP will be fully compensated through a tariff increase or reimbursement.

Group Captive Open-Access Projects: For Open Access projects, structuring projects in a group captive model [74] is the primary strategy to mitigate regulatory uncertainty (i.e., large increases in existing or new Open Access charges). The EA exempts group captive projects from the Cross Subsidy Surcharge and Additional Surcharge (AS), which together form a substantial portion of total Open Access charges [73,74]. Group captives have become the default model after most states withdrew charge waivers for third party RE projects in 2019 [73]. Group captive procurement is cheaper than grid tariffs in most states. Important exceptions include Gujarat, which does not permit it, and Maharashtra, which levied a new 1.31/kWh AS on group captives [73].

4.7. Inflation risk

4.7.1. Description

Unexpectedly high inflation is a significant and systematically underestimated sector risk. High inflation can damage realized EIRRs through increasing plant CapEx and debt servicing costs.

Several factors make sector investments especially vulnerable to inflation risk. First, the sector has fixed-price PPAs with (0–4%) annual escalation not linked to inflation. Second, 90% of power is sold through long-term bilateral PPAs. RE generators don't sell significant amounts of power on the thin spot market, which could offer inflation protection. Third, due to extreme competitive market pressure, IPPs often make aggressively low tariff bids with little room for unexpected costs. Fourth, IPPs typically assume 3–4% annual inflation over a 15–25 year PPA lifetime. This is significantly lower than India's Consumer Price Index (CPI) [121] over the last decade (Fig. 15).

Inflation risk is presently a growing global concern due to pandemic-related macroeconomic forces: unprecedented expansive monetary and fiscal stimulus, widespread supply-chain shortages, and home-shoring of supply chains including PV. In India, Mono-crystalline PERC [122] PV module prices have increased by 25% over the last year [123]. Concurrently, Indian CPI has twice surpassed [124] the Reserve Bank of India's (RBI) 2–6% inflation comfort range, prompting speculation of a potential rise in interest rates. Recent modelling [106] of PV projects aggressively bid at Rs 2.0/kWh (the record low bids in 2020), suggests that at present \$0.26/W Mono-PERC prices, a 1% rise in financing rates (from 8 to 9%), would push project Debt Service Coverage Ratios into default territory [68].

4.7.2. Mitigation strategies

Derivative hedging: Derivatives can be purchased to hedge large unexpected inflation movements over the PPA-lifetime. Most IPPs, however, do not hedge for inflation due to their cost-sensitivity in a competitive environment, belief that future inflation will be 4% (as evidenced in 2016–2020), and a business strategy to sell project-equity after the initial few years.

Debt strategies: Investors can mitigate interest rate movements by financing with appropriate rate assumptions, taking on long-tenor fixed-rate debt (e.g., fixed coupon bullet bonds), and borrowing in USD [27, 125] at a fixed coupon rate.

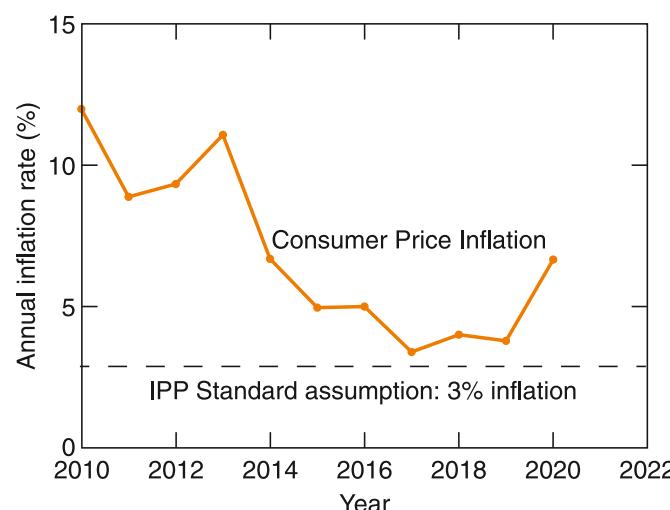


Fig. 15. Annual Indian Consumer Price Inflation over the last decade. Data from RBI.

4.8. Foreign exchange rate risk

4.8.1. Description

Investors ultimately care about returns in the currency they have obligations in: debt repayment for IPPs, payouts to limited partners for PE funds, or pension payments for institutional investors. Investors get exposed to foreign exchange risk if there is a mismatch between their currency of ultimate interest and the Rupee, in which they harvest RE asset cash-flows.

In their financial models, most investors assume 4–5% annual INR depreciation against the dollar, comparable to observed depreciation [126] over the last decade. Higher rupee depreciation over a plant's life due to high Indian economic growth and/or high inflation, will compromise investor returns.

4.8.2. Mitigation strategies

Currency hedging: Market-based hedging is expensive in the Indian derivatives market [27] due to lack of volume and liquidity. The cost of fully hedging INR cash-flows is 7–8%, undermining equity returns and often eliminating basis arbitrage between borrowings in foreign vs. domestic markets [27].

Global portfolio diversification: In a globally diverse portfolio [31] with cash-flows from various currencies, losses from one particular currency can get offset by gains from a different currency. Most foreign institutional investors have such protection through global diversification mandates.

4.9. Tail risk

4.9.1. Description

RE assets face investment tail risk due to cyberattacks and electromagnetic pulses triggered by a solar geomagnetic storm or a manmade thermonuclear detonation [127,128]. Such events can severely impair or shut down the grid, producing widespread offtaker default under PPA *force majeure* clauses [129]. Recent high profile cyberattacks demonstrate how tangible such tail risk is. Kudankulam, India's largest nuclear power plant, was cyberattacked in 2019 [130] and a segment of the Mumbai electricity grid was shut down by alleged Chinese hackers in 2020 [131]. As India faces increasing Cyberattacks [132] from hostile adversaries ranging from Pakistan [133] to China and North Korea [134], tail risk will increase substantially.

4.9.2. Mitigation strategies

Investors cannot directly mitigate tail risk, but they can gain protection by:

Purchasing insurance: Hedging through purchasing appropriate insurance [135].

Lobbying to harden the Indian grid: Lobby the Indian government to harden the electric grid against such risks, as Chinese, North Korean, and Russian governments have already done [136].

5. Offtaker strength analysis

5.1. Central offtaker risk analysis

5.1.1. Perceived security with central offtakers

IPPs now strongly prefer contracting through central offtakers versus directly with state DisComs due to their perceived lower risk. Central offtakers' auction capacity volumes have overtaken those of state DisComs since 2016 (Fig. 16) [68]. Their auctions attract lower IPP tariffs with 200 bp lower EIRRs. In M&A transactions, investors are willing to pay "full value" for assets backed by SECI/NTPC PPAs due to certainty of timely payment [67].

Central offtakers are considered very bankable because of their following characteristics detailed below: sovereign parentage, SECI Payment Security Fund, tripartite agreements, and large auction

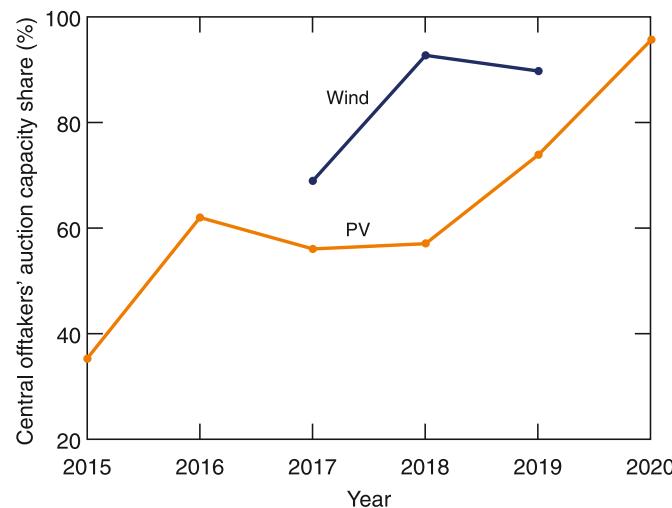


Fig. 16. Central offtaker's annual share of total auctioned Indian utility scale PV and wind capacity. Data courtesy of CEEW and the IEA [68].

volumes.

NTPC and SECI have sovereign parentage since they are, respectively, 56% and 100% owned by the Centre. Both play a strategically important role in the RE sector, a high Centre priority. In this context, investors view NTPC/SECI PPAs as quasi-sovereign guarantees. Both NTPC/SECI have an established history of timely payments (Fig. 12), with no instances of breaching contracts.

Furthermore, SECI maintains a Payment Security Fund (PSF) to protect against DisCom payment delay/default, lack of grid access for power evacuation, and other delays/defaults. The PSF is a cash reserve that provides generators interest-free working capital if these events occur. If a DisCom defaults and LC/default escrow agreements provide insufficient coverage, SECI can access PSF funds to pay a generator the balance amount (within 21 days of default). The DisCom must pay SECI the equivalent amount plus delay charges to replenish PSF reserves within ten days of SECI's payment to the generator. If a DisCom does not pay after six months from the payment due date, SECI can enforce its last resort protection through tripartite agreement (described below). Furthermore, in the case of persistent defaults, SECI has the right to divert generated power to a third party. The PSF is presently \$164 million large (6/21) [137].

NTPC/SECI are also beneficiaries of the tripartite agreement, a contract between the Centre, RBI, and states. If a DisCom repeatedly defaults, the agreement authorizes the Centre to request the RBI to debit the amount due in the state's RBI account, and credit the equivalent amount to the account of NTPC/SECI. SECI has invoked the agreement several times to collect late dues from DisComs in AP and Karnataka [138]. Tripartite agreements serve as significant deterrents to DisCom payment delays and defaults [70,94].

NTPC and SECI also have very large auction volumes and they are expected to tender 6–8 GW of RE capacity per year for the next 7–10 years [67], providing IPPs the opportunity to build attractive large scale project portfolios.

Some investors interviewed stated they feel more comfortable contracting with NTPC than SECI due to its significantly larger balance sheet and longer-standing relationship with DisComs. However, our comprehensive examination of SECI vs NTPC RE auctions (conducted at similar time and place) does not elicit any significant differences in tariffs and implied risk premiums.

5.1.2. Risks with central offtakers

SECI and NTPC PPAs are exposed to multiple risks.

The primary risk is counterparty risk. Fundamentally, RE-trading cash-flows for central offtakers accrue from credit-weak DisComs. This

exposure has historically resulted in large payment delays from several DisComs [70].

Related counterparty risks accrue from *back-to-back* PPA clauses. Recent SECI/NTPC PPAs (since 2019) contain new *back-to-back* clauses limiting their fulfilment of significant obligations only if they are fulfilled by DisComs [66]. These clauses limit SECI/NTPC liabilities and pose clear, non-trivial risks to generators. New fine print emphasizes that SECI/NTPC are only power trading intermediaries and links a PPA signed between SECI/NTPC and a generator to a PSA between SECI/NTPC and the DisCom. This unambiguously establishes the DisCom as the ultimate counterparty and negates any interpretation implying pooling of counterparties with respect to each PPA signed. Furthermore, only generator tariff payment obligations (*i.e.*, monthly bills, supplementary bills and change-in-law payments) are direct obligations of SECI/NTPC. Every other obligation is pass-through. This means that critical PPA obligations like opening an LC, creating a payment security fund, and compensation for grid issues, will be met by SECI/NTPC only if DisComs comply with the obligations. Tellingly, LCs obligations have rarely been created for recently signed SECI/NTPC PPAs [66]. The PPAs also limit SECI/NTPC liabilities under several DisCom default scenarios. For example, if a relevant SERC does not adopt a DisCom's tariff within two months of PPA signing, the PPA stands cancelled with no liability to SECI/NTPC, substantially jeopardizing the IPPs. Additionally, DisCom payment delays under a PSA and repudiation of the corresponding PPA can trigger termination of the PPA, with no liability for SECI/NTPC [66]. Rigorous risk analysis of these updated SECI/NTPC PPAs must consider the risk profile of the specific *back-to-back* counterparty (*i.e.*, specific DisCom).

Furthermore, the inapplicability of PSF to new schemes must be adequately accounted for when assessing risks with central offtakers. The PSF presently only applies to capacities tendered under the Nehru Solar Mission (Phase II: Batch I, III, IV). If other auctioned capacities experience DisCom default and leave SECI with an immediate cash shortfall, SECI would need to cope using internal funds, taking on external borrowings, or requesting immediate liquidity injection from MNRE [70]. SECI has been criticised [139–141] for too quickly assuming rapidly growing payment liabilities to IPPs (30x liability increase between 2016 and 2022 [14]). To deal with growing liabilities, SECI has requested MNRE to extend the existing PSF to all new auction schemes, and recently required auction bidders to deposit \$7000/MW on commissioning assets for PSF use [70].

5.2. DisCom offtaker risk analysis

Among state DisComs, Gujarat's four DisComs (part of the GUVNL holding group) are regarded as the unparalleled strongest offtakers. They are the only DisComs with a decade long track record⁸ of sustained profitability, low AT&C losses, and timely 30 day (and often early) payment times. Gujarat auctions generally command low-tariffs and investor EIRRs on par with those of NTPC/SECI, implying a comparable perceived risk premium [68]. To evaluate other state DisComs, IPPs and investors must do deeper due diligence. Among interviewees, the seven most commonly used metrics to assess DisCom strength were identified as:

1. Credit rating
2. Average payment days
3. Expected area electricity supply–demand gap
4. Debt finance credit rating

⁸ In 2000 The Gujarat Electricity Board (the precursor to GUVNL DisComs) was among the worst performing utilities in India, negatively impacting state finances and development. A decade-long, strategic management turnaround, fully backed by politicians and employee stakeholders, transformed GUVNL into a model public utility [142].

5. Track record of PPA renegotiation/cancellation
6. Degree of revenue dependence on state subsidies
7. State government fiscal strength (proxy for capacity to sustain DisCom subsidies)

5.3. C&I offtaker risk analysis

C&I IPPs mitigate offtaker risk by signing PPAs with A to BBB credit-rated corporations. This market-segment—approximately 800 companies across India—represents only 5% of Indian corporations [143]. Some IPPs discount external credit ratings believing they do not accurately reflect the likelihood of a prospect to reliably make payments over 15–25 years. Such IPPs rely on their own proprietary assessment of prospects with heavier weightage on their corporate governance and business stability. Instances of payment delay or PPA renegotiation/cancellation are very rare for strong corporate offtakers since electricity is an essential business necessity and, for certain industrial manufacturers 30–40% [74] of their total expenditures. In the event of aggressively delayed payments, IPPs can punitively curtail electricity, forcing offtakers to procure higher-cost grid tariffs and face protracted legal proceedings.

Narrow IPP focus on the strongest corporate offtakers, has left most of the non-traditional potential buyers underserved: unrated and lower-rated corporations, SMEs, non-profit institutions, and residential customers. It is challenging to reliably assess the creditworthiness, and long-term business/cash-flow stability of these potential customers due to limited availability of reliable data and/or IPP/customer information asymmetry.

After concluding that a non-traditional prospect has stable cash-flows and an enduring long-run incentive to procure cheaper-than-grid electricity IPPs are typically unable to raise project debt financing. For such customers IPPs expect high 15–20%+ Rs EIRRs to compensate for the risk and typically choose CAPEX projects [73,74], where customers pay all upfront costs.

Recently, some corporate buyers have experienced credit-rating downgrades due to Covid-19 related financial challenges—resulting in higher tariffs for new PPAs [73]. IPPs are now performing increased due diligence on corporate-buyers' market positions, relationships with vendors, and GST filing trends [73]. IPPs are introducing new PPA damage-mitigation clauses in the event of future pandemics and other *force majeure* events [73]. On the other hand, pandemic related financial-challenges are prompting increasing numbers of corporate and lower-tier buyers to explore purchasing corporate-PPAs to improve their operating leverage.

6. Why do investors invest despite the risks?

Despite the risks presented in this paper, the RE sector is still able to attract billions of dollars in investment from existing and new investors every quarter. These facts raise the question: *Why are investors deploying capital in the RE sector despite all the risks?*

Our primary research suggests that in the face of significant risks, investors are deploying sizable capital because they are confident of India's long-run robust demand for RE (8–10 GW/year) [67,144], driven by policy and market forces and the Centre's commitment to resolve sector issues. Investors are further encouraged by the bankability of central offtakers as intermediate procurers, overriding DisComs' distress and their conviction that the judiciary will adequately uphold contracts in the long-run. Finally, investors are driven by the fundamentals of sector investment value: 7–10% USD EIRRs, large market size, high deal liquidity and ESG-mandate fit [145].

7. Open questions on sector risk outlook

The Indian RE sector is changing rapidly with new policies, market players, and technology improvements every quarter. Amidst rapid

change, we encourage stakeholders to inform their sector risk outlook by continuously assessing the following questions:

7.1. How sustainable is intermediary central offtake?

As intermediary offtakers, SECI/NTPC are playing a crucial sector role in increasing investor confidence, despite DisComs' poor creditworthiness. If DisComs finances are not sustainably fixed, SECI/NTPC could eventually have last-resort liabilities for 100s of GW worth of PPAs—posing risk to Centre finances and taxpayers [14]. In event of a financial crisis, the Centre may be forced to suddenly retroactively cut RE obligations, as EU countries did with their unsustainable RE Feed-in-Tariffs [146–148] after the Great Financial Crisis.

7.2. How quickly will tariffs fall?

The trajectory of new RE project tariffs (*i.e.*, continuing fast declines) will shape future PPA signing delay/renegotiation and stranded asset risks. Tariffs will be determined by PV module costs and financing costs. Present drivers for higher module costs are inflationary pressures, supply-chain bottlenecks, silver price increases⁹, module made-in-India auction requirements [150], and announced 40% import duty ([151]). Competing drivers for lower module cost are PERC technology improvements [149] and manufacturing scale-up [152], and fierce manufacturer competition. Financing costs will be determined by evolving international/domestic interest rates, plus the sector risk premium.

7.3. How will the procurement model change?

If RE production costs continue to decline, they will lead to value deflation of incremental RE added to the grid and growing RE grid integration challenges. Furthermore, offtakers will have disincentive to honour older, higher-priced RE and thermal PPAs. These forces, coupled with increasing inflation-risk for IPPs, will likely push both IPPs and offtakers to increase spot market transactions. Spot procurement can help offtakers lower their long-run procurement costs. Spot sales can help IPPs minimize offtaker, curtailment, stranded asset, and inflation risks. India's spot market is currently thin and illiquid; long-term PPAs dominate, accounting for 88% of generation volume [153]. Widespread adoption of the following emerging procurement models [73] will dramatically change incentives/risks for all stakeholders: Round-the-clock PPAs, Real time market trading, the Green Term-Ahead market, derivatives for the short-term market, Virtual PPAs, and Interstate PPAs.

7.4. How likely is major sector reform?

There are growing calls for major power sector reforms to address underlying structural failures. This urgency for reform has heightened amidst strained central and state government finances from the Covid-19 crisis. The three most frequently advocated reform proposals are DisCom privatization [82,84,154], separating carriage and content [80, 84], and a direct-benefit transfer (DBT) electricity subsidy [155]. These three reform proposals are comprehensively detailed in SM Table II If any of the three reforms is successfully implemented, it would largely resolve offtaker/stranded asset risk attributable to DisCom financial weakness.

⁹ Silver is used for the front surface electrode of PERC cells due to its high conductivity and corrosion-resistance. Silver costs represent approximately 5–6% of total module costs and the PV industry currently uses 10% of annual supply [149]. The PV industry has historically been unable to find scalable low-cost replacement electrode materials. Growing demand in electronics, bio-medical devices, and other clean-energy technologies, coupled with investor interest in hedging macroeconomic inflation, could cause large silver price increases this decade.

Among the three reforms proposals, the DBT scheme likely has the greatest chance of widespread implementation across India due to the following practical advantages: First, target beneficiaries (i.e., currently important voter blocks) will transparently continue to receive subsidized electricity and have no incentive to oppose it. Second, politicians, regulators, and DisCom officials will retain their existing authority resulting in no incentive to oppose it. Third, DBT schemes have already been successfully proven for liquid propane gas [156,157] and rural job guarantee [158] subsidies across India. Fourth, as part of Covid-stimulus reform measures, the Centre has already successfully motivated two states (Madhya Pradesh and AP) to implement farmer DBT schemes to replace free/subsidized power, in return for increased Centre borrowing limits [159]. Both states will expand their DBT pilot programs state-wide in FY21-22. Moving forward, it likely that the BJP-party-led Centre will collaborate with BJP-led states to implement more electricity DBT schemes. DisCom privatization could be coupled with DBT implementation to improve DisCom operations and protect the poor from higher privately-set tariffs.

8. Conclusion

The Centre has set an ambitious 450 GW RE target for 2030 to meet India's enormous power demand growth. The required new financing of \$600 bn dwarfs present sector capital flow. Mobilizing increased capital will only be possible if stakeholders are confident they can navigate the sector's significant investment risks.

This work builds upon theoretical and empirical studies on the impact of RE investment risks in emerging and developed economies published over the last two decades. We have complemented this body of work by presenting insights on Indian RE sector risks distilled from 40 primary field interviews with relevant leading sector stakeholders. We have discussed nine strategic RE investment risks and corresponding mitigation strategies. We have emphasized that offtaker risk is the most dominant, and inflation risk and tail risk, the most underappreciated. All nine risks will likely increase in the future.

Risks derive from politicization of the power sector, poor legal contract enforceability, a competitive market environment of rapidly falling RE tariffs, and inflexible power procurement models. These have led to a *status quo* where project execution is difficult, and DisComs have neither the ability nor incentive to make timely payments, honour contracts, and facilitate private distributed RE projects.

Prior efforts to reform DisComs—including three bailouts in the last eight years—have failed to make lasting improvements because the Centre has limited constitutional ability to unilaterally reform the power sector. It instead can only rely upon its soft power to incentivize or coax states to reform.

Central offtakers now dominate utility-scale auction capacity as intermediaries to insulate IPPs from directly contracting with risky DisComs. Presently billions of dollars have been invested in this large market for 7–9% USD returns and growth opportunities. Current investors have confidence in NTPC/SECI's bankability and the Centre's commitment to resolve sector issues. These investors, however, are neither investing at the levels nor the rate required to meet India's 450 GW target. The ultimate resolution to offtaker/stranded asset risks would be a combination of major policy reform and adoption of more flexible power procurement models. How, if, and when these transpire remains uncertain.

All eyes are watching India navigate its energy transition. If India can mobilize the capital and execution to achieve its 450 GW RE target, not just India, but the entire world stands to benefit. India's transformation into a sustainable global superpower would set a powerful example for other emerging markets and make earth's climate safer for us all.

Author contributions

H.H.G. proposed the study, conducted research interviews, wrote the

first manuscript draft, and designed the figures. B.H. and B.J.H. supervised the work. All authors edited the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

H.H.G. acknowledges support from the Harvard University Frank A. Knox Traveling Memorial Fellowship and the Australian American Association Graduate Education Scholarship Award. H.H.G. would like to thank the following individuals for providing figure data: Vinay Rustagi, Arjun Arora and Samriti Chawla (Bridge to India), Vikram V (ICRA), Rahul Tongia and D. Rajasekhar (CSEP), Gagan Sidhu (CEEW) and IEA, and Vandana Gombar and Megan Green (BNEF). H.H.G. would especially like to thank Amma for guidance during the conception of this work and all interviewees for sharing their experience and insights B.H. and B.J.H. would like to thank the Australian Renewable Energy Agency (ARENA) and the Australian Centre for Advanced Photovoltaics (ACAP) for their continuing support.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.esr.2022.100921>.

References

- [1] Aaron O'Neill. India, Estimated Total Population from 2016 to 2026, June 28, 2021. Statista 2021, <https://www.statista.com/statistics/263766/total-population-on-india/>.
- [2] S. Agrawal, S. Mani, D. Aggarwal, H. Kumar, A. Jain, K. Ganesan, Awareness and Adoption of Energy Efficiency in Indian Homes Insights from the India Residential Energy Survey (IRES 2020), Council of Energy, Environment, and Water Centre for Energy Finance, 2020.
- [3] M. Abbas, India Has 22 Cars Per 1,000 Individuals: Amitabh Kant, The Economic Times, Dec 12, 2018. <https://auto.economictimes.indiatimes.com/news/passenger-vehicle/cars/india-has-22-cars-per-1000-individuals-amitabh-kant/67059021>.
- [4] International Energy Agency, India Energy Outlook 2021, International Energy Agency, Paris, France, 2021.
- [5] Country GDP Per Capita, The World Bank Data Bank, September 15, 2021. <https://data.worldbank.org/indicator/NY.GDP.PCAP.CD>.
- [6] Country Per Capita Electricity Consumption, Our World In Data, September 15, 2021. <https://ourworldindata.org/grapher/per-capita-electricity-consumption>.
- [7] P. Laha, B. Chakraborty, Low carbon electricity system for India in 2030 based on multi-objective multi-criteria assessment, Renew. Sustain. Energy Rev. 135 (2021), 110356, <https://doi.org/10.1016/j.rser.2020.110356>.
- [8] M.K. Hairat, S. Ghosh, 100 GW solar power in India by 2022 – a critical review, Renew. Sustain. Energy Rev. 73 (2017) 1041–1050, <https://doi.org/10.1016/j.rser.2017.02.012>.
- [9] R. Singh, Energy sufficiency aspirations of India and the role of renewable resources: scenarios for future, Renew. Sustain. Energy Rev. 81 (2018) 2783–2795, <https://doi.org/10.1016/j.rser.2017.06.083>.
- [10] G. Shrimali, S. Rohra, India's solar mission: a review, Renew. Sustain. Energy Rev. 16 (2012) 6317–6332, <https://doi.org/10.1016/j.rser.2012.06.018>.
- [11] R. Quitzow, Assessing policy strategies for the promotion of environmental technologies: a review of India's National Solar Mission, Res. Pol. 44 (2015) 233–243, <https://doi.org/10.1016/j.respol.2014.09.003>.
- [12] V. Khare, S. Nema, P. Baredar, Status of solar wind renewable energy in India, Renew. Sustain. Energy Rev. 27 (2013) 1–10, <https://doi.org/10.1016/j.rser.2013.06.018>.
- [13] G. Shrimali, N. Agarwal, C. Donovan, Drivers of solar deployment in India: a state-level econometric analysis, Renew. Sustain. Energy Rev. 133 (2020), 110137, <https://doi.org/10.1016/j.rser.2020.110137>.
- [14] R. Gadre, A. Jain, J. Shantanu, G. Vandana, T. Dario, India's Clean Energy Revolution: A Success Story with Global Implications, Bloomberg New Energy Finance (BNEF), 2020.
- [15] Bridge To India, Utility Scale Solar Capacity, India RE Navigator, October 24, 2021 d. <https://india-re-navigator.com/utility>.
- [16] IRENA. International, Renewable Energy Capacity Statistics 2021, International Renewable Energy Agency (IRENA), 2021.
- [17] Bridge to India, Information from Private Data Set provided by Bridge to India, 2021.

[18] Global Wind Report 2021, Global Wind Energy Council, 2021.

[19] T. Matsuo, T.S. Schmidt, Managing tradeoffs in green industrial policies: the role of renewable energy policy design, *World Dev.* 122 (2019) 11–26, <https://doi.org/10.1016/j.worlddev.2019.05.005>.

[20] K. Ivanovski, A. Hailemariam, R. Smyth, The effect of renewable and non-renewable energy consumption on economic growth: non-parametric evidence, *J. Clean. Prod.* 286 (2021), 124956, <https://doi.org/10.1016/j.jclepro.2020.124956>.

[21] M. Olleik, H. Auer, R. Nasr, A petroleum upstream production sharing contract with investments in renewable energy: the case of Lebanon, *Energy Pol.* 154 (2021), 112325, <https://doi.org/10.1016/j.enpol.2021.112325>.

[22] M. Olleik, H. Hamie, H. Auer, Using natural gas resources to de-risk renewable energy investments in lower-income countries, *Energies* 15 (2022) 1651, <https://doi.org/10.3390/en15051651>.

[23] P.A. Owusu, S. Asumadu-Sarkodie, A review of renewable energy sources, sustainability issues and climate change mitigation, *Cogent Eng.* 3 (2016), 1167990, <https://doi.org/10.1080/23311916.2016.1167990>.

[24] A. Vishnoi, India's 450GW target listed in US "Energy Compact" as climate goal, *The Economic Times* (October 2, 2021). <https://economictimes.indiatimes.com/industry/renewables/indiass-450gw-target-listed-in-us-energy-compact-as-climate-goal/articleshow/86698245.cms?from=mdr>.

[25] The Hindu Business Line Bureau, Banks Free to Have Separate Caps for Lending to Power. Renewables Sectors: RBI to Centre, August 1, 2019. <https://www.thehindubusinessline.com/economy/banks-free-to-have-separate-caps-for-lending-to-power-renewables-sectors-rbi-to-centre/article28787168.ece>.

[26] S. Manju, N. Sagar, Progressing towards the development of sustainable energy: a critical review on the current status, applications, developmental barriers and prospects of solar photovoltaic systems in India, *Renew. Sustain. Energy Rev.* 70 (2017) 298–313, <https://doi.org/10.1016/j.rser.2016.11.226>.

[27] G. Shrimali, Financial instruments to address renewable energy project risks in India, *Energies* 14 (2021) 6405, <https://doi.org/10.3390/en14196405>.

[28] Council On Energy, Environment And Water, CEEW Centre for Energy Finance, Payment delays – the weakest link in India's energy transition? CEEW Cent Energy Finance Mastercl (2020). <https://cef.ceew.in/masterclass/analysis/payment-delays-weakest-link-in-india-energy-transition>.

[29] T. Buckley, K. Shah, India's Renewable Energy Policy Headwinds, Institute For Energy Economics and Analysis, February 2020.

[30] C. Anupam, Paradigm Shift: Andhra Govt Charts Out DBT Plan for Power Subsidy to Farmers, The Financial Express, September 5, 2020. <https://www.financialexpress.com/economy/paradigm-shift-andhra-govt-charts-out-dbt-plan-for-power-subsidy-to-farmers/2075414/>.

[31] K. Chawla, Money Talks? Risks and Responses in India's Solar Sector, Council of Energy, Environment, and Water Centre for Energy Finance, New Delhi, India, 2016. <https://www.ceew.in/publications/money-talks>.

[32] K. Chawla, A. Ghosh, Greening New Pastures for Green Investments, Council of Energy, Environment, and Water Centre for Energy Finance, 2019.

[33] CEEW Centre for Energy Finance Class, Andhra Pradesh – sending investors packing, even if contracts are upheld, Council On Energy, Environment And Water (July 31, 2019) accessed May 4, 2021, <https://cef.ceew.in/masterclass/analysis/andhra-pradesh-sending-investors-packing-even-if-contracts-are-upheld>.

[34] L.H. Sendstad, M. Chronopoulos, Sequential investment in renewable energy technologies under policy uncertainty, *Energy Pol.* 137 (2020), 111152, <https://doi.org/10.1016/j.enpol.2019.111152>.

[35] W. Blyth, R. Bradley, D. Bunn, C. Clarke, T. Wilson, M. Yang, Investment risks under uncertain climate change policy, *Energy Pol.* 35 (2007) 5766–5773, <https://doi.org/10.1016/j.enpol.2007.05.030>.

[36] O. Tourinho, The Valuation of Reserves of Natural Resources: an Option Pricing Approach, Ph.D. Thesis, University of California, Berkeley, 1979.

[37] R. Adkins, D. Paxson, Subsidies for renewable energy facilities under uncertainty: subsidies under uncertainty, *Manch. Sch.* 84 (2016) 222–250, <https://doi.org/10.1111/manc.12093>.

[38] G. Blackman, R. Zeckhauser, *Fragile commitments and the regulatory process*, *Yale J. Regul.* 9 (1992) 73–106.

[39] X. Liu, M. Zeng, Renewable energy investment risk evaluation model based on system dynamics, *Renew. Sustain. Energy Rev.* 73 (2017) 782–788, <https://doi.org/10.1016/j.rser.2017.02.019>.

[40] A. Masini, E. Menichetti, The impact of behavioural factors in the renewable energy investment decision making process: conceptual framework and empirical findings, *Energy Pol.* 40 (2012) 28–38, <https://doi.org/10.1016/j.enpol.2010.06.062>.

[41] UNEP Finance Initiative, *Financing Renewable Energy in Developing Countries: Drivers and Barriers for Private Finance in Sub-Saharan Africa*, United Nations, 2012.

[42] A. Boute, Regulatory stability and renewable energy investment: the case of Kazakhstan, *Renew. Sustain. Energy Rev.* 121 (2020), 109673, <https://doi.org/10.1016/j.rser.2019.109673>.

[43] A. Boute, Improving the climate for European investments in the Russian electricity production sector: (I) the role of investment protection law, *J. Energy Nat. Resour. Law* 26 (2008) 267–302, <https://doi.org/10.1080/02646811.2008.11435186>.

[44] G. Bond, L. Carter, Financing energy projects, *Energy Pol.* 23 (1995) 967–975, [https://doi.org/10.1016/0301-4215\(95\)00099-2](https://doi.org/10.1016/0301-4215(95)00099-2).

[45] Z.Y.I. Abba, N. Balta-Ozkan, P. Hart, A holistic risk management framework for renewable energy investments, *Renew. Sustain. Energy Rev.* 160 (2022), 112305, <https://doi.org/10.1016/j.rser.2022.112305>.

[46] J. Barroco, M. Herrera, Clearing barriers to project finance for renewable energy in developing countries: a Philippines case study, *Energy Pol.* 135 (2019), 111008, <https://doi.org/10.1016/j.enpol.2019.111008>.

[47] A. Malhotra, T.S. Schmidt, L. Haelg, O. Waissbein, Scaling up finance for off-grid renewable energy: the role of aggregation and spatial diversification in derisking investments in mini-grids for rural electrification in India, *Energy Pol.* 108 (2017) 657–672, <https://doi.org/10.1016/j.enpol.2017.06.037>.

[48] K. Kim, H. Park, H. Kim, Real options analysis for renewable energy investment decisions in developing countries, *Renew. Sustain. Energy Rev.* 75 (2017) 918–926, <https://doi.org/10.1016/j.rser.2016.11.073>.

[49] N.V. Emodi, S.D. Yusuf, Improving electricity access in Nigeria: obstacles and the way forward, *Int. J. Energy Econ. Pol.* 5 (2015) 335–351.

[50] L.H. Sendstad, V. Hagspiel, W.J. Mikkelsen, R. Ravndal, M. Tveitstøl, The impact of subsidy retraction on European renewable energy investments, *Energy Pol.* 160 (2022), 112675, <https://doi.org/10.1016/j.enpol.2021.112675>.

[51] S. Chassot, N. Hampl, R. Wüstenhagen, When energy policy meets free-market capitalists: the moderating influence of worldviews on risk perception and renewable energy investment decisions, *Energy Res. Social Sci.* 3 (2014) 143–151, <https://doi.org/10.1016/j.erss.2014.07.013>.

[52] D. Angelopoulos, H. Doukas, J. Psarras, G. Stamatidis, Risk-based analysis and policy implications for renewable energy investments in Greece, *Energy Pol.* 105 (2017) 512–523, <https://doi.org/10.1016/j.enpol.2017.02.048>.

[53] P.A.O. Dalby, G.R. Gillerhaugen, V. Hagspiel, T. Leth-Olsen, Thijssen Jjj, Green investment under policy uncertainty and Bayesian learning, *Energy* 161 (2018) 1262–1281, <https://doi.org/10.1016/j.energy.2018.07.137>.

[54] L. Eyraud, A. Abdoul, C. Zhang, B. Clements, Who's Going Green and Why? Trends and Determinants of Green Investment, International Monetary Fund Working Paper, International Monetary Fund, December 2011. <https://www.imf.org/external/pubs/ft/wp/2011/wp11296.pdf>.

[55] J. Gamel, K. Menrad, T. Decker, Is it really all about the return on investment? Exploring private wind energy investors' preferences, *Energy Res. Social Sci.* 14 (2016) 22–32, <https://doi.org/10.1016/j.erss.2016.01.004>.

[56] L. Bird, D. Lew, M. Milligan, E.M. Carlini, A. Estanqueiro, D. Flynn, et al., Wind and solar energy curtailment: a review of international experience, *Renew. Sustain. Energy Rev.* 65 (2016) 577–586, <https://doi.org/10.1016/j.rser.2016.06.082>.

[57] Vivek Sen, Kuldeep Sharma, Gireesh Shrimali, Reaching India's Renewable Energy Targets: the Role of Institutional Investors, Climate Policy Initiative, 2016.

[58] Vaibhav Pratap Singh, Arjun Dutt, Sidu Gagan, RE-financing India's Energy Transition: Limited Period Subsidised Credit Enhancement for Domestic RE Bond Issuances, Council of Energy, Environment, and Water Centre for Energy Finance, 2020.

[59] The Constitution of India, 1950.

[60] N. Menon, A. Akshita, Electricity Regulation in India, Lexology, 2020. <https://trilegal.com/wp-content/uploads/2022/01/India-Chapter-Electricity-Regulation-2020.pdf>.

[61] S.L. Rao, The political economy of power, *Economic Political Weekly* 37 (No.33) (2002) 3433–3444. <https://www.jstor.org/stable/4412491>.

[62] Government of India, The Electricity Act, 2003, 2003.

[63] Power Finance Corporation LTD, Report on Performance of State Power Utilities 2018–2019, 2020.

[64] N.T.P.C. Overview, Ntpc Ltd 2021. <https://www.ntpc.co.in/en/about-us/ntpcoverview>.

[65] H. Shukla, NTPC Targets 60 GW of Renewable Energy Capacity by 2032, October 2, 2021. Mercom India 2021, <https://mercomindia.com/ntpc-target-renewable-energy-capacity/>.

[66] D. Charen, in: SECI and NTPC PPAs, *Discom Profile Is Integral for Counterparty Analysis*, India Ratings and Research, 2019.

[67] A. Malik, Sprng CEO on Growth Plans, Solar Valuations and what Investors Want, VCC Circle, November 27, 2020. <https://www.vccircle.com/actis-aggarwal-spring-ceo-on-growth-plans-solar-valuations-and-what-investors-want>.

[68] A. Dutt, L. Arboleya, P. Gonzalez, K. Chawla, M. Waldron, Clean Energy Investment Trends 2020: Mapping Project-Level Financial Performance Expectations in India, The Council on Energy, Environment and Water. The International Energy Agency and The International Energy Agency, 2020. <https://www.ceew.in/cef/solutions-factory/clean-energy-investment-trends-2020.in>.

[69] A.S. Bose, S. Sarkar, India's e-reverse auctions (2017–2018) for allocating renewable energy capacity: an evaluation, *Renew. Sustain. Energy Rev.* 112 (2019) 762–774, <https://doi.org/10.1016/j.rser.2019.06.025>.

[70] Solar Energy Corporation of India Ltd, Long-term Rating Upgraded and Short-Term Rating Reaffirmed, ICRA, 2021.

[71] S.D. Das, R. Srikanth, Viability of power distribution in India – challenges and way forward, *Energy Pol.* 147 (2020), 111882, <https://doi.org/10.1016/j.enpol.2020.111882>.

[72] G. Shrimali, Financial performance of renewable and fossil power sources in India, *Sustainability* 13 (2021) 2573, <https://doi.org/10.3390/su13052573>.

[73] World Business Council for Sustainable Development, Corporate Renewable PPAs in India: Market and Policy Update January 2021, World Business Council for Sustainable Development, 2021.

[74] World Business Council for Sustainable Development, Accelerating Corporate Procurement of Renewable Energy in India, World Business Council for Sustainable Development, 2018.

[75] A. Amirapu, Justice delayed is growth denied: the effect of slow courts on relationship-specific industries in India, *Econ. Dev. Cult. Change* 70 (2021) 415–451, <https://doi.org/10.1086/711171>.

[76] The World Bank. Enforcing Contracts: Ease of Doing Business Report, The World Bank, September 15, 2021. <https://www.doingbusiness.org/en/data/exploretopics/enforcing-contracts>.

[77] A. Verma, Combating Corruption in India/Arvind Verma, Ramesh Sharma, Cambridge University Press, Cambridge, United Kingdom ; New York, NY, 2019.

[78] Central Electricity Authority, Methodology for Calculation of ACS-ARR Gap, Government of India Ministry of Power Central Electricity Authority Distribution and Planning Division, 2017.

[79] Sheoli Pargal, Sudesna Ghosh Banerjee, More Power to India the Challenge of Electricity Distribution, The World Bank, Washington DC, 2014.

[80] CSIR Infrastructure Advisory, Revenue Security, World Utility Summit, 2020. CSIR, 2020.

[81] Government of India Ministry of Power, About UDAY n.D, October 24, 2021. <http://www.uday.gov.in/about.php>.

[82] R. Tongia, DisComs Post-COVID-19: Untangling the Historical Challenges, Short-Term Needs and Long-Term Ambitions, Brookings Institution India Centre, 2020.

[83] D. Rajasekhar, R. Tongia, Reconciling DisCom 'Stimulus' and Dues: We Must Look beyond the Tip of the Iceberg, Centre for Social and Economic Progress, 2020.

[84] S. Majumdar, G. Kadam, V. Vikram, Distribution Sector Reforms Imminent with Rising Discom Debt and Dues to Gencos, ICRA Ltd, 2021.

[85] Government of India Ministry of Power, PRAAPTI - Payment Ratification and Analysis in Power Procurement for Bringing Transparency in Invoicing of Generators n.D, October 26, 2021. <http://www.praapti.in/>.

[86] T. Buckley, V. Garg, India's Power Distribution Sector Needs Further Reform, Institute For Energy Economics and Analysis, 2020.

[87] R. Tongia, India's Biggest Challenge: the Future of Farming, India Forum, Sept 30, 2019. <https://www.theindiaforum.in/article/india-s-biggest-challenge-future-farming>.

[88] Government of India National Power Portal, National power portal glossary AT&C losses. www.npp.gov.

[89] A.P. Chikktar, A.D. Sagar, N. Abhyankar, N. Sreekumar, Tariff-based incentives for improving coal-power-plant efficiencies in India, Energy Pol. 35 (2007) 3744–3758, <https://doi.org/10.1016/j.enpol.2007.01.006>.

[90] G. Sidhu, K. Shah, The Case for Indexed Renewable Energy Tariffs, Institute For Energy Economics and Analysis, 2020.

[91] D. Singh, R. Tongia, Need for an Integrated Approach for Coal Power Plants, Centre for Social and Economic Progress, 2021. <https://csep.org/discussion-note-need-for-an-integrated-approach-for-coal-power-plants/>.

[92] Christopher Beaton, Anjali Viswamohan, Prateek Aggarwal, How can India's energy sector recover sustainably from COVID-19? International Institute for Sustainable Development (August 27, 2020). <https://www.iisd.org/articles/how-can-indias-energy-sector-recover-sustainably-covid-19>. April 24, 2022.

[93] T. Buckley, V. Garg, S. Nicholas, K. Shah, Seriously Stressed and Stranded: the Burden of Non-performing Assets in India's Thermal Power Sector, Institute For Energy Economics and Analysis, 2019.

[94] V. Atal, G. Shrimali, V.P. Singh, Addressing Off-Taker Risk in Renewable Projects in India: A Framework for Designing Payment Security Mechanism as a Credit Enhancement Device, Climate Policy Initiative, 2018.

[95] S. Chakravorty, Land acquisition in India: the political-economy of changing the law, Area Dev. Pol. 1 (2016) 48–62, <https://doi.org/10.1080/23792949.2016.1160325>.

[96] Ministry of New Renewable, India Wind Energy Overview, Government of India, 2021. <https://mnre.gov.in/wind/current-status/>. September 29, 2021.

[97] A. Mohan, Whose land is it anyway? Energy futures & land use in India, Energy Pol. 110 (2017) 257–262, <https://doi.org/10.1016/j.enpol.2017.08.025>.

[98] S.S. Nandamrui, V. Rustagi, India Renewable Power CEO Survey 2020, Bridge to India, 2020.

[99] V. Garg, J. Gulia, Backlog of Unsigned Power Sale Agreements Risks Slowing India's Renewable Energy Growth, Institute For Energy Economics and Analysis, 2021.

[100] U. Gupta, Gujarat 700 MW Award Cancellation Will Impact Solar Investment, Pv Magazine India, 2021. <https://www.pv-magazine-india.com/2021/02/12/gujarat-700-mw-award-cancellation-will-impact-solar-investment/>. May 3, 2021.

[101] U. Gupta, Solar Tariff Drops below INR 2/kWh, Pv Magazine India, 2020. <https://www.pv-magazine-india.com/2020/12/22/solar-tariff-drops-below-inr-2-kwh/>. May 3, 2021.

[102] N.T. Prasad, in: Another Bad Precedent, Gujarat Regulator Allows DISCOM to Scrap 700 MW Solar Auction, Mercom India, 2021. <https://mercomindia.com/gujarat-regulator-scrapes-solar-auction/>. May 3, 2021.

[103] Financial Express Bureau, Gujarat to Re-tender 700 MW Solar Projects to Seek Lower Tariff, The Financial Express, February 1, 2021. <https://www.financialexpress.com/industry/gujarat-to-re-tender-700-mw-solar-projects-to-seek-lower-tariff/2183419/>.

[104] Information from Private Data Set provided by ICRA, 2021.

[105] S. Raikar, S. Adamson, Renewable Energy Finance: Theory and Practice, Elsevier Academic Press, London ; San Diego, CA, 2020.

[106] S. Majumdar, G. Kadam, V. Vikram, M. Gopidi, Increasing Regulatory Constraints amid Weak Discom Finances a Challenge for Third-Party Open Access Based Renewable Power Projects, ICRA Ltd, 2021.

[107] Kaavya Chandrasekaran, Arijit Barman, Ray of hope as Andhra Pradesh starts clearing renewable dues this week, Economic Times (Jan 4, 2020). <https://economictimes.indiatimes.com/industry/energy/power/ray-of-hope-as-andhra-pradesh-starts-clearing-renewable-dues-this-week/articleshow/73091210.cms?from=mdr>.

[108] U. Bhaskar, Andhra Pradesh's green energy investors now fear loan recall, Mint (Sept 9, 2020). <https://www.livemint.com/industry/energy/andhra-pradesh-green-energy-investors-now-fear-loan-recall-11599638201228.html>.

[109] S. Manju, N. Sagar, Renewable energy integrated desalination: a sustainable solution to overcome future fresh-water scarcity in India, Renew. Sustain. Energy Rev. 73 (2017) 594–609, <https://doi.org/10.1016/j.rser.2017.01.164>.

[110] kWh Analytics, Solar Risk Assessment 2020: Quantitative Insights from Industry Experts, 2020.

[111] D. Chen, M. Vaqueiro Contreras, A. Ciesla, P. Hamer, B. Hallam, M. Abbott, et al., Progress in the understanding of light- and elevated temperature-induced degradation in silicon solar cells: a review, Prog. Photovoltaics Res. Appl. (2020) 3362, <https://doi.org/10.1002/pip.3362>.

[112] D. Singhal, S. Suresh, S. Arora, S. Singhvi, V. Rustagi, Water Use in Solar Power Sector, Bridge to India, 2018.

[113] L. Bird, J. Cochran, X. Wang, Wind and Solar Energy Curtailment: Experience and Practices in the United States, 2014, <https://doi.org/10.2172/1126842>.

[114] Council on Energy Environment and Water, Oftake risks: the buck stops here, Centre for Energy Finance Masterclass (July 16, 2019). <https://www.ceew.in/cef/masterclass/analysis/oftake-risks-the-buck-stops-here>.

[115] S. Prateek, Green Energy Corridor Is Underfunded, Says Standing Committee on Energy, Mercom India, 2019. <https://mercomindia.com/green-energy-corridor-underfunded/>.

[116] J. Thakur, B. Chakraborty, Intelli-grid: moving towards automation of electric grid in India, Renew. Sustain. Energy Rev. 42 (2015) 16–25, <https://doi.org/10.1016/j.rser.2014.09.043>.

[117] B. Stott, Review of load-flow calculation methods, Proc. IEEE 62 (1974) 916–929, <https://doi.org/10.1109/PROC.1974.9544>.

[118] J.A. Martinez, J. Mahseredjian, Load Flow Calculations in Distribution Systems with Distributed Resources. A Review, IEEE Power Energy Soc. Gen. Meet., San Diego, CA, 2011, pp. 1–8, <https://doi.org/10.1109/PES.2011.6039172>. IEEE; 2011.

[119] B. Utpal, Higher GST from today likely to affect solar power rates, Mint (October 1, 2021) (accessed October 26, 2021), <https://www.livemint.com/industry/energy/higher-gst-from-today-likely-to-affect-solar-power-rates-11633027983200.html>.

[120] B. Utpal, Steep import duty on solar cells, modules from Apr '22, Mint (2021) (accessed October 26, 2021), <https://www.livemint.com/news/india/india-to-impose-steep-customs-duty-on-solar-cells-modules-from-april-2022-11615387885538.html>.

[121] D. Goel, Aryabhatta College, University of Delhi, New Delhi 110021, India. Measures of inflation in India, J. Bus. Thought 9 (2018) 24–45, <https://doi.org/10.1831/jbt/2018/21171>.

[122] M.A. Green, The passivated emitter and rear cell (PERC): from conception to mass production, Sol. Energy Mater. Sol. Cells 143 (2015) 190–197, <https://doi.org/10.1016/j.solmat.2015.06.055>.

[123] JMK Research, Analytics, RE Monthly Update (August 2021) 2021.

[124] S. Bhat, Monetary Policy Support to India Economy Should Continue - MPC Minutes, Reuters, 2021.

[125] A.A. Farooque, G. Shrimali, Making renewable energy competitive in India: reducing financing costs via a government-sponsored hedging facility, Energy Pol. 95 (2016) 518–528, <https://doi.org/10.1016/j.enpol.2016.02.005>.

[126] CompareRemit, History of The US Dollar vs. Indian Rupee, CompareRemit, 2021 (accessed October 26, 2021), <https://www.compareremit.com/money-transfer-guide/the-rise-and-fall-of-the-dollar-vs-rupee-since-1947>.

[127] M. Johnson, Elliott Founder Reveals His Dread of Electromagnetic Pulse, Financial Times, July 29, 2014. <https://www.ft.com/content/e1aa9680-1741-11e4-87c0-00144feabdc0>.

[128] Lloyd's of London, Solar Storm Risk to the North American Electric Grid, 2013.

[129] A. Koundal, Understanding Force Majeure - ET Energy World, ET EnergyWorld, March 29, 2020. <https://energy.economictimes.indiatimes.com/news/renewable/understanding-force-majeure/74876447>.

[130] D. Das, An Indian Nuclear Power Plant Suffered a Cyberattack. Here's what You Need to Know, The Washington Post (November 4 2019). <https://www.washingtonpost.com/politics/2019/11/04/an-indian-nuclear-power-plant-suffered-cyberattack-heres-what-you-need-know/>.

[131] D.E. Sanger, E. Schmalz, China Appears to Warn India: Push Too Hard and the Lights Could Go Out, The New York Times, March 1, 2021. <https://www.nytimes.com/2021/02/28/us/politics/china-india-hacking-electricity.html>.

[132] IANS Economic Times, EconomicTimesCIO (February 25, 2021) second only to Japan in Asia Pacific in cyberattacks faced in 2020 - ET CIO, <https://cio.economictimes.indiatimes.com/news/digital-security/india-second-only-to-japan-in-asia-pacific-in-cyberattacks-faced-in-2020/81190638>.

[133] IANS, India Sees dramatic rise in cyber attacks post-Kashmir decision, Mint (August 19, 2019). <https://www.livemint.com/news/india/india-sees-dramatic-rise-in-cyber-attacks-post-kashmir-decision-1566217795883.html>.

[134] S. Jung, E. White, S. Findlay, Suspected North Korean hackers targeted Indian space agency, Financial Times (November 7, 2019). <https://www.ft.com/content/ae6a8782-ffad-11e9-b7bc-f3fa4e77dd47>.

[135] Chaos from above an electromagnetic pulse event triggered by the detonation of a low-yield nuclear device in Earth's atmosphere triggers economic and societal chaos, Risk Insurance (July 27, 2017). <https://riskandinsurance.com/chaos-from-above/>. October 26, 2021.

[136] T. Koppel, Lights Out: a Cyberattack, a Nation Unprepared, Surviving the Aftermath, first ed., Crown Publishers, New York, 2015.

[137] Status of PSM Fund, Solar Energy Corporation India, Government of India, 2021. <https://www.seci.co.in/financial/psm>.

[138] U. Bhaskar, SECI moves to claim Andhra's dues from central devolution, Mint (December 11, 2019). <https://www.livemint.com/politics/policy/seci-moves-to-claim-andhra-s-dues-from-central-devolution-11576030816991.html>.

[139] M. Rajshekhar, India's solar sector bearing the costs of a poorly designed market, The Wire (June 25, 2021) (accessed October 2, 2021), <https://thewire.in/energy/indiassolar-sector-bearing-the-costs-of-a-poorly-designed-market>.

[140] R. Ranjan, Unsigned Power Sale Agreements — A Major Hurdle for Growth in the Solar Sector, Mercom India, Feb 26, 2021, <https://mercomindia.com/unsigned-power-sale-agreements>.

[141] R. Ranjan, Should solar generators worry about SECI amid rising dues from DISCOMs? Mercom India (October 28, 2020). <https://mercomindia.com/should-solar-generators-worry/>.

[142] T. Shah, M. Mehta, G. Sankar, Reform in Gujarat's electricity utility: lessons for revitalizing a bureaucratic service delivery agency, in: Water Policy Research Highlight, vol. 6, IWMI-Tata Water Policy Program, Gujarat, India, 2012.

[143] V. Gombar, International Groups Spot Allure of India Rooftop Solar: Q&A, Bloomberg New Energy Finance, 2019 (accessed May 6, 2021), <https://about.bnef.com/blog/international-groups-spot-allure-of-india-rooftop-solar-qa/>.

[144] India added >10 GW of solar and wind capacity in the first nine months of 2021. JMK Res Anal 2021. <https://jmkresearch.com/india-added-10-gw-of-solar-and-wind-capacity-in-the-first-nine-months-of-2021/> (accessed October 26, 2021).

[145] T. Thomas, The great games at play in wind and solar, Mint (2020) (accessed November 27, 2020), <https://www.livemint.com/industry/energy/the-great-games-at-play-in-wind-and-solar-11594735981374.html>.

[146] C. Leepa, M. Unfried, Effects of a cut-off in feed-in tariffs on photovoltaic capacity: evidence from Germany, Energy Pol. 56 (2013) 536–542, <https://doi.org/10.1016/j.enpol.2013.01.018>.

[147] Y. Karneyeva, R. Wüstenhagen, Solar feed-in tariffs in a post-grid parity world: the role of risk, investor diversity and business models, Energy Pol. 106 (2017) 445–456, <https://doi.org/10.1016/j.enpol.2017.04.005>.

[148] B. Cointe, A. Nadaï, Feed-in Tariffs in the European Union: Renewable Energy Policy, the Internal Electricity Market and Economic Expertise, first ed., Springer International Publishing, Cham, 2018 <https://doi.org/10.1007/978-3-319-76321-7>. Imprint: Palgrave Macmillan; 2018.

[149] International Technology Roadmap for Photovoltaic Results, 2020, p. 2021.

[150] PTI, Azure top bidders for manufacturing-linked solar tender, The Economic Times (Jan 17, 2020). <https://m.economictimes.com/small-biz/productline/power-generation/adani-azure-top-bidders-for-manufacturing-linked-solar-tender/articleshow/73322552.cms>.

[151] U. Gupta, Solar modules to face 40% customs duty, and cells 25%, from next year, Pv Magazine India (March 10, 2021) (accessed May 6, 2021), <https://www.pv-magazine-india.com/2021/03/10/solar-modules-to-face-40-customs-duty-cells-25-from-april-next-year/>.

[152] M.A. Green, How Cheap Can Photovoltaics Become?. University of New South Wales School of Photovoltaic and Renewable Energy Engineering Lecture SPREE Lecture Series, December 19, 2020. <https://www.youtube.com/watch?v=NDTml5OXZwA>.

[153] V. Garg, Deepening India's Short-Term Power Market with Derivatives New Financial Products Will Boost National Trading of Renewable Energy, Institute For Energy Economics and Analysis, 2021.

[154] Power Line Magazine, Redefining distribution updates on DFs and UT discom privatization, Power Line Magazine (August 30, 2021). <https://powerline.net.in/2021/08/30/redefining-distribution/>. November 29, 2021.

[155] S. Aggarwal, DBT in electricity distribution holds the key for power reforms: Sanjeev Aggarwal. Amplus Solar CEO, ET EnergyWorld.com, The Economic Times, February 26, 2020. <https://energy.economictimes.indiatimes.com/news/renewable/dbt-in-electricity-distribution-holds-the-key-for-power-reforms-sanjeev-aggarwal-ceo-amplus-solar/74303578>. (Accessed 26 January 2021).

[156] N. Chindarkar, A. Jain, S. Mani, Examining the willingness-to-pay for exclusive use of LPG for cooking among rural households in India, Energy Pol. 150 (2021), 112107, <https://doi.org/10.1016/j.enpol.2020.112107>.

[157] N. Mittal, A. Mukherjee, A. Gelb, Fuel Subsidy Reform in Developing Countries: Direct Benefit Transfer of LPG Cooking Gas Subsidy in India, The Center for Global Development, Washington DC, 2017.

[158] K. Deininger, Y. Liu, Heterogeneous welfare impacts of national rural employment guarantee scheme: evidence from Andhra Pradesh, India, World Dev. 117 (2019) 98–111, <https://doi.org/10.1016/j.worlddev.2018.12.014>.

[159] The Hindu Business Line Bureau, Madhya Pradesh Becomes First State to Give Power Subsidy to Farmers through DBT, The Hindu Business Line 19 (January 2019). <https://www.thehindubusinessline.com/news/national/madhya-pradesh-becomes-first-state-to-give-power-subsidy-to-farmers-through-dbt/article33611726.ece>.