Electricity Sector Transformation in India

A Case Study of Tamil Nadu

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Executive Summary

The Indian state of Tamil Nadu provides an excellent case study of the potential to transform a regional electricity system, progressively increasing reliance on renewables whilst at the same time lowering average cost of electricity supply and sustaining a strongly growing economy.

India has set ambitious plans to diversify its electricity production into zero-emissions, lower cost alternatives at the same time as it doubles installed capacity over the coming decade.

The 2016/17 year was a transformational one for India. Compared to the previous four years, thermal power installations dropped by 60% to just 8 gigawatts (GW) of net new capacity, while renewable energy installations more than doubled to a record 15.7 GW. These trends have continued in 2017/18, and IEEFA is confident they will accelerate going forward.

IEEFA bases this forecast on the clear tipping point achieved in 2017; new renewable investments are being underwritten at tariffs of Rs2.43-3.00/kilowatt-hour (kWh), below the average tariff paid to NTPC, India's largely central government-owned power generator, for thermal power in 2016/17 of Rs3.20/kWh.

Tamil Nadu (TN) already operates the most diversified electricity generation fleet in India, with renewables representing 35% of installed capacity as of March 2017, nuclear 8% and hydroelectricity 7%. Coal-fired power capacity represents 45% or 13.4 GW. Tamil Nadu represented almost one fifth (18.5%) of India's total renewable energy generation in 2016/17.

IEEFA has modelled expected electricity demand and supply for Tamil Nadu, mapping a deflationary trajectory that also builds in a progressive diversification away from the current over-reliance on increasingly imported fossil fuels:

- **Electricity production climbs to 164 terawatt-hours (TWh) by 2026/27, an increase of 60TWh or 57%.** Deducting 2026/27 12.7% AT&C losses gives net demand in TN of 143 TWh, a rise of 60 TWh or 72% over the decade. This is predicated on 7% real annual gross domestic product (GDP) growth, in line with IEEFA's forecast for India overall. Total installed capacity expands to a forecast 55 GW by 2026/27. IEEFA projects a more modest 5.6% compound annual growth rate (CAGR) in TN electricity demand over the coming decade.
- **IEEFA forecasts 67% of installed capacity and 56% of generation in Tamil Nadu will be derived from zero-emissions technologies by 2026/27**. Distributed battery storage, demand response management, further diversification of generation capacity across fuel types, solar thermal power, pumped hydro storage (e.g. 500 megawatts (MW) at Kundah) and interstate grid connectivity will each play a key enabling role to accommodate a progressively higher market share of variable renewable energy sources.
- **Onshore and offshore wind capacity additions will provide an estimated 41% of the production uplift needed**. As of March 2017, Tamil Nadu has 7.85 GW of wind operational. This makes Tamil Nadu one of the largest states in the world in terms of operational wind farms. August 2017 saw the finalization of a 500 MW wind tender by TANGEDCO at a near TN state record low tariff of Rs3.42/kWh. IEEFA models a near doubling to 15.0 GW of operational wind by 2026/27 across Tamil Nadu, including from **repowering** end-of-life projects to attain a tenfold uplift in capacity at existing facilities.

IEEFA expects **offshore wind** to emerge as a new, cost competitive source of electricity generation system diversification for Tamil Nadu by 2025.

- **IEEFA forecasts that Tamil Nadu will see total solar installs increase sixfold by 2027**. As of June 2017 Tamil Nadu is no longer the top state in India in terms of installed solar capacity. Ministry of New and Renewable Energy (MNRE) data show that Tamil Nadu, with an installed capacity of 1,697 MW, has now fallen into third position behind Andhra Pradesh (2,010 MW) and Rajasthan (1,961 MW).

  Solar capacity is forecast to reach 12 GW of utility scale plus 1.5 GW across the residential and commercial & industrial (C&I) rooftop sectors, providing one-third of all new generation needs this coming decade. Tamil Nadu is the leading state in India with respect to rooftop solar. As of March 2017, installs totaled 163 MW, 12% of India's total. If Tamil Nadu can maintain its sector leadership, this would imply 1-2 GW of rooftop solar is a conservative target by 2026/27, requiring 100-200 MW annually over the coming decade.

  The addition of 10.3 GW of new utility-scale solar by 2026/27 looks entirely commercially feasible after the 1.5 GW solar auction of July 2017 at just Rs3.47/kWh.

- **Market share of coal-fired generation falls from 69% to just 42% in IEEFA's model**. IEEFA calculates the average Tamil Nadu coal-fired power plant operated at 62% in 2016/17, well below design targets of 75-85%. Total coal-fired capacity is forecast to reach 16.6 GW by 2026/27, and utilisation rates will collapse to an entirely unsustainable 45% average by that date (with expensive to run imported coal-fired power plant utilisation rates falling faster, given the cost advantage of domestic pithead lignite generation).

  With 22.5 GW of new coal-fired power generation capacity announced for Tamil Nadu, there is a growing stranded asset risk for thermal power companies. New non-pithead thermal coal-fired capacity requires tariffs in excess of Rs5.50/kWh, entirely failing to deliver cost-effective solutions for TN customers.

- **TANGEDCO's improving financial profile is forecast to move into a net profit for the first time in two decades within 2-3 years**. Critical to any sustained momentum in the Indian electricity sector transformation is a solution to the financial distress of the states' distribution companies. Ongoing losses at Tamil Nadu Generation and Distribution Corp. (TANGEDCO), have been a major constraint on electricity sector progress. TANGEDCO's 2016/17 loss has been reduced by three quarters in just three years to Rs3,783 crores (US$582m). June 2017 saw the announcement that TANGEDCO was targeting a breakeven profit result for 2017/18. IEEFA views this as overly optimistic, but the path is set for better than breakeven results within the next few years.

With 72 million people, Tamil Nadu is a state that is bigger in population than most countries around the world. The ability to rapidly shift to a progressively greater reliance on lower cost, zero-emissions generation sources is illustrative for many emerging markets internationally.

Absent replacement of end-of-life thermal capacity, Tamil Nadu does not need any new thermal power capacity this coming decade. Building new thermal capacity will just further depress existing low utilisation rates and create further financial distress for the thermal power sector.

Introduction

IEEFA holds enormous confidence that India is increasingly embracing an accelerating electricity sector transformation, moving up alongside China as a new world leader in this, the Asian Century. The merits of energy transition are multiple: lowering dependence on fossil fuel imports; improving India's energy security; reducing India's increasingly chronic air and water pollution pressures; accelerating domestic and foreign investment into India's renewable and grid infrastructure; bringing much needed high quality employment growth; baking in a deflationary trajectory for energy prices for the first time in many decades; and building on the "Make in India" vision that will drive the value-added manufacturing and exports needed to sustainably grow the economy at the 7% annual target.

This report provides an analysis of the state of Tamil Nadu's electricity system and the likely investment pathway over the coming decade to 2026/27. IEEFA has modelled expected electricity demand and supply for Tamil Nadu, mapping a deflationary trajectory for wholesale electricity costs that also builds in a steady diversification away from the state's current over-reliance on increasingly imported fossil fuels.

Reducing losses from India's distribution companies (Discoms) is critical for the transformation and long-term health of India's electricity sector. The Tamil Nadu Generation and Distribution Corporation (TANGEDCO) was slow to buy-in to the central government's utility reform program, Ujwal Discom Assurance Yojana (UDAY), but the progress made in the last two years has been staggering and will serve Tamil Nadu well in the coming decade. Progress is evident across several key parameters: a sustained reduction in the unmet power deficit; a material reduction in the average cost of supply (ACS) of electricity (thanks to ever lower solar and wind tariffs); higher average revenue received (ARR), some reduction of aggregate technical & commercial (AT&C) grid losses, particularly theft and corruption; the benefits of refinancing and restructuring off-balance TANGEDCO debts; and most recently now exporting renewable energy to other states at a premium to its acquisition cost (Rs5-6/kWh vs Rs3-4/kWh cost).

TANGEDCO reported a record unfunded loss of Rs13,985 crore (US$2.1bn) in 2013/14 and the ongoing financial distress has been a major constraint on electricity sector progress in TN. June 2017 saw TN Electricity Minister P Thangamani report that TANGEDCO's 2016/17 loss has been reduced by three quarters in just three years to Rs3,783 crore (US$582m). One benefit of TANGEDCO's improving performance is that renewable energy costs will continue to decline as the bankability of the company's PPAs continue to improve.

IEEFA's confidence in the sustained nature of the electricity sector transformation in Tamil Nadu can be traced to two interconnected developments: the significant reform progress at TANGEDCO and the fact that Tamil Nadu is the leading state in India in terms of renewables penetration, driving ongoing wholesale electricity price deflation.

Tamil Nadu is home to NLC India Ltd (NLCIL), the integrated lignite mining and pithead power generation company that is the largest electricity generator in the state, generating power at around Rs4/kWh. However, as Tamil Nadu's electricity demand continues to grow at 5-6% annually, the state has put in place what IEEFA believes are entirely unrealistic plans to treble thermal power capacity. This would rapidly build a reliance on imported liquefied natural gas (LNG) and thermal coal sourced largely from either Indonesia or central-eastern India, the later requiring coal transportation of over 1,650 kilometres. These new thermal power

proposals all come at a prohibitive cost of electricity (Rs5-6/kWh). This looks increasingly ridiculous given Tamil Nadu's leading renewable energy capacity of 10.6 GW and scope to treble renewable infrastructure in the coming decade at costs of Rs2-4/kWh.

Tamil Nadu has a total proposed coal-fired power plant pipeline of 22.5 GW, a staggering increase from the 13.4 GW of existing coal-fired capacity as of March 2017. IEEFA would highlight that collapsing utilisation rates are making even the existing coal plants less competitive with each passing year (the utilisation rate of TN's coal fleet in 2016/17 was an estimated 61.7%, a 10-year low). Add in the high cost of transporting thermal coal to Tamil Nadu, plus falling renewable energy tariffs, and TN's coal-fired PPAs of Rs4.91-5.23/kWh are increasingly uncompetitive and unjustifiable. Building yet more expensive, non-pithead coal-fired power capacity is entirely unviable and involves trying to get the already distressed financial and distribution sectors to fund stranded assets in the making, whilst expanding already problematic issues of water stress, flyash disposal and site rehabilitation.

NLCIL's decision in October 2017 to cancel its long proposed 3.96 GW coal-fired power plant at Sirkazhi village is a clear confirmation of these ongoing changes. NLCIL justified the cancellation by stating the import coal plant required a tariff of more than Rs5.50/kWh, significantly above both the prevailing renewables rate (Rs2-4/kWh) and that of pithead lignite power generation (Rs3-4/kWh). This is a sensible start to the rationalisation process, but IEEFA forecasts many more cancellations will follow. This should start with cancelling the decade-long plan for the Cheyyur Ultra Mega Power Plant (UMPP), a clear stranded asset proposal, and 3.75 GW of end-of-life coal plant closures by 2026/27.

Managing an increasing proportion of variable renewable energy capacity is an issue that must be addressed by stronger grid integration planning. TANGEDCO's proposed 500 MW Kundah Pumped Storage Hydroelectric facility and the central government's Interstate Green Power Corridor are key upgrades important to help facilitate this transition.

IEEFA also identifies two final opportunities:

1. The enormous scope for repowering: Tamil Nadu has 7.9 GW of installed onshore wind capacity, most of which was built more than 20 years ago. This makes Tamil Nadu the leading state in India in terms of wind capacity, and one of the largest in the world. But with these wind farms rapidly reaching the end of their useful life, there is an immediate US$5-10bn investment opportunity to repower or upgrade existing wind farms using modern wind turbines of 2-3 MW of capacity each, a near tenfold increase in output vs the existing 200-500 kW turbines currently in place.

2. The launch of India's offshore wind sector: Tamil Nadu should invest in a 1 GW offshore wind farm by 2026/27, laying the learning by doing foundations for a US$20-30bn investment in 10 GW of offshore wind infrastructure in the subsequent decade.

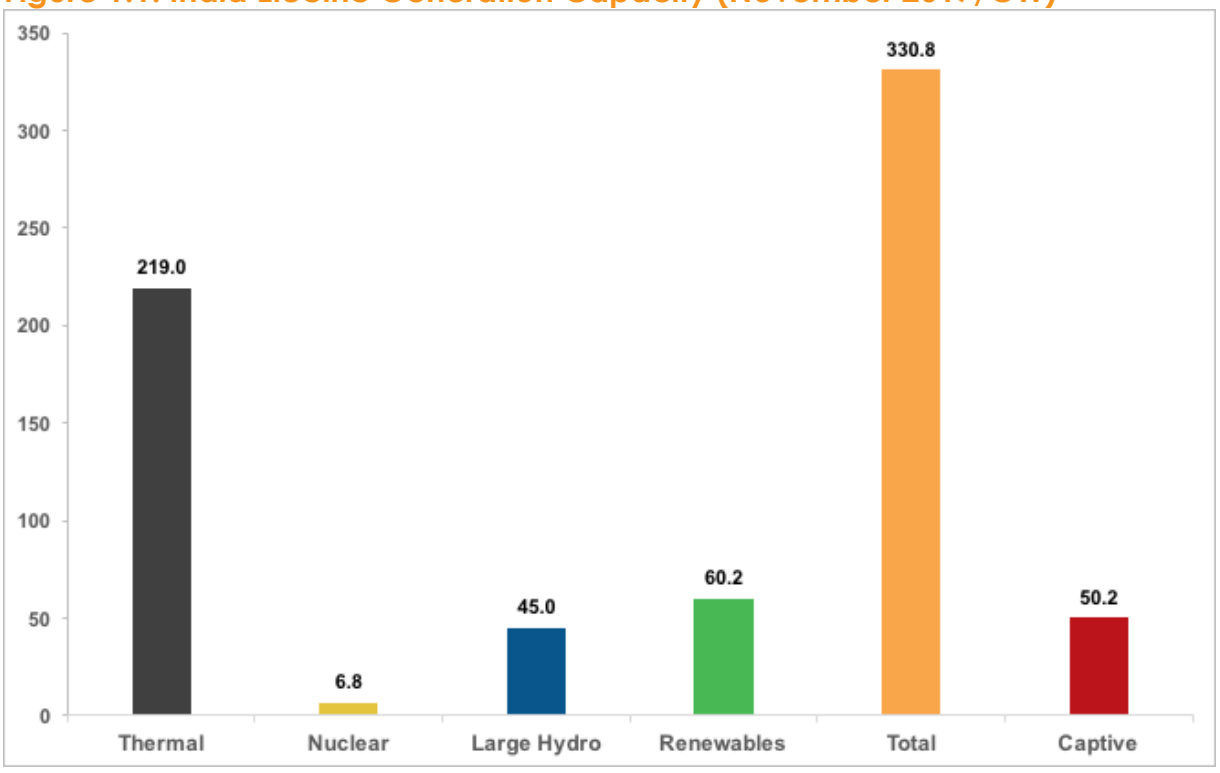
Tamil Nadu is a fascinating case study showing how renewable energy can cost-effectively meet rising electricity needs while enabling the development of a more diverse, more distributed, less carbon- intense generation sector. The deflationary benefits started to emerge in 2017, and this requires a radical rethink of existing plans to build up to US$20bn of new thermal power capacity dependent on imported fuels—plans that will almost immediately become stranded assets if IEEFA's TN electricity model is even roughly accurate.

1. India's Electricity Sector

The Indian electricity market is undertaking a major transformation: at the same time as it is expanding capacity to meet an expected doubling in demand in the coming decade, the government of India is leading a major effort to diversify supply. Coal-fired power supplied 76% of total generation in 2016/17; IEEFA forecasts the market is on-track to reduce this over-dependence on coal to just 57% by 2026/27. This unprecedented loss of market share for coal reflects the new economic realities being created by technology and finance-driven disruption. Beyond the obvious merits of systemic real price deflation, India is developing a less-polluting, more sustainable energy system far better suited to meeting its economic needs. Additional energy security benefits come from reduced reliance on inflationary fossil fuel imports and the job creation opportunities from a US$500bn investment across India's electricity system in the coming decade.

Thermal power (coal, diesel and gas) currently represents 219 GW or 66% of India's total installed on-grid capacity of 331 GW. With an average utilisation rate of 57% in 2016/17, thermal power provided 80% of total electricity generation in 2016/17 (Figure 1.1).

Figure 1.1: India Electric Generation Capacity (November 2017/GW)

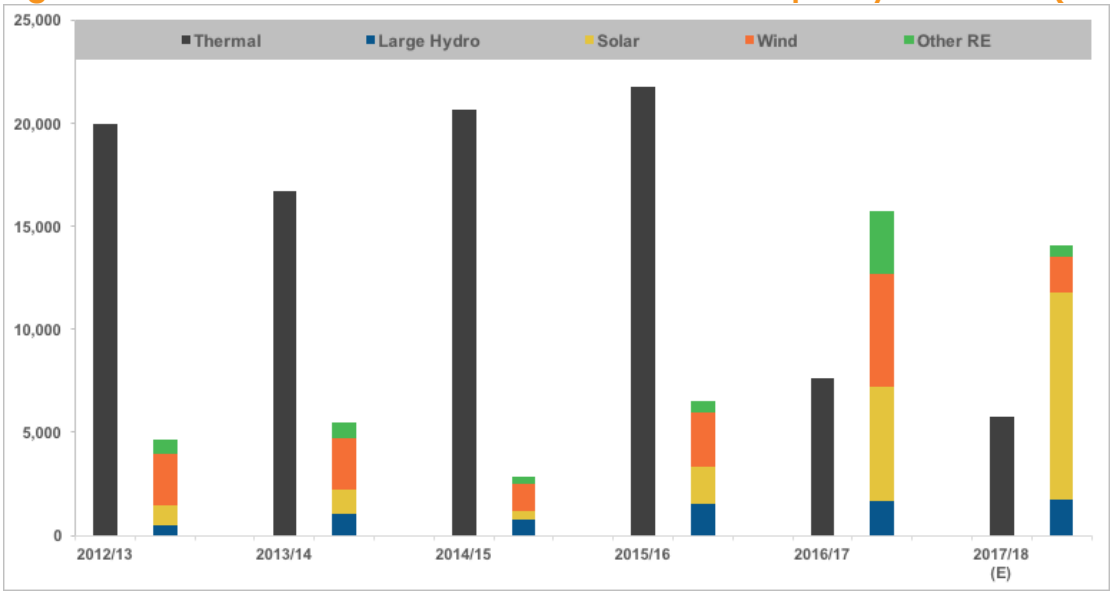


Source: Central Electricity Authority (CEA)

The growth of renewable infrastructure investment in India has been driven by concerns over air and water pollution, international climate commitments relating to carbon emission control, the need to improve energy security and reduce reliance on fossil fuel imports, and, most prominently by the rapidly falling price of renewable energy.

The 2016/17 year was transformational for India: During that year just 8 GW of net new thermal capacity came online, a 60% drop compared to the previous four year average. At the same time, renewable energy installations more than doubled to a record 15.7 GW (Figure 1.2). These trends continued in 2017/18, and IEEFA is confident they will accelerate as the new decade unfolds.

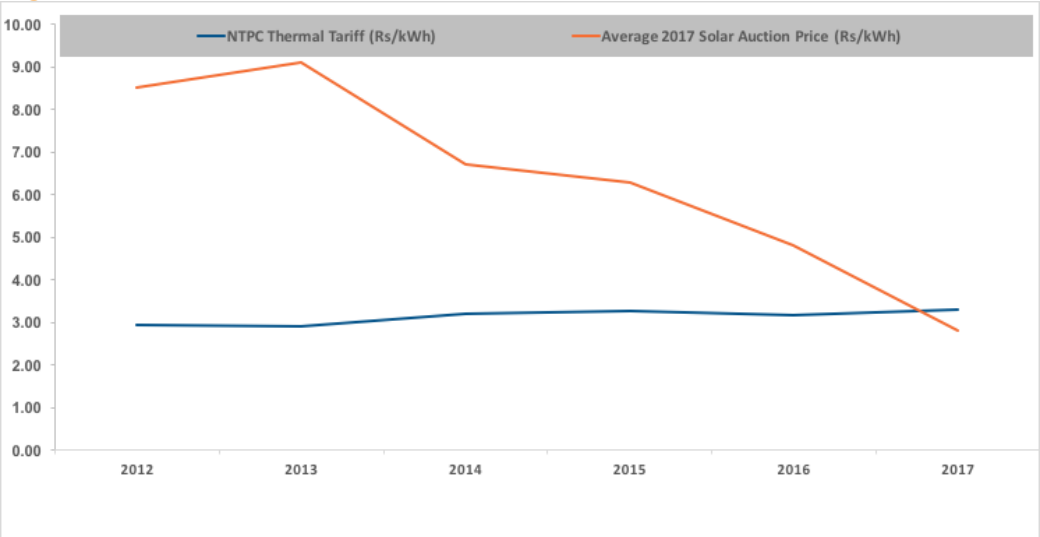
Figure 1.2: India Renewable and Thermal Power Capacity Additions (MW)



Source: Central Electricity Authority, MNRE, IEEFA Estimates

IEEFA bases this non-consensus forecast on the clear tipping point achieved in 2017; new renewable investments are being underwritten at tariffs of Rs2.43-3.00/kWh, below the average tariff paid to NTPC for thermal power in 2016/17 of Rs3.20/kWh (Figure 1.3).

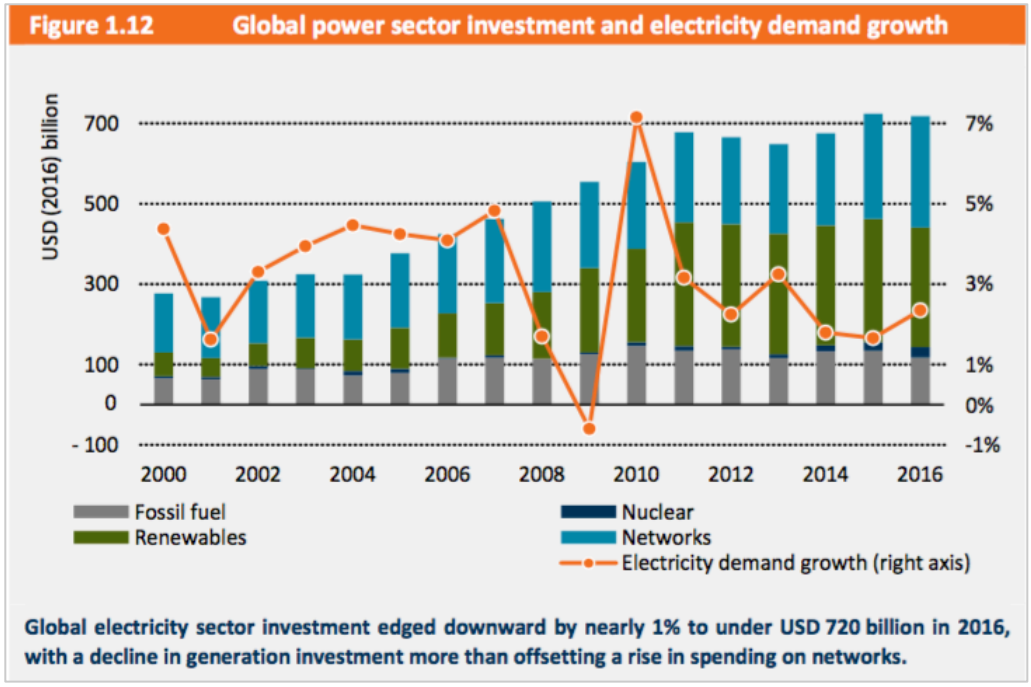
Figure 1.3: Indian Solar Tariffs Vs NTPC's Coal-Fired Power Tariff 2012-2017 (Rs)



Source: NTPC, Bloomberg New Energy Finance, Livemint, Bloomberg Gadfly, IEEFA estimates

The International Energy Agency (IEA) has tracked global investment in the electricity sector for years (Figure 1.4). The same trend is evident globally—the value of investment in renewable energy installations has been running at 2-3 times the rate of investment in thermal power since 2010, with the differential expanding each year. Given that technology and economies of scale are delivering double digit annual cost reductions for renewable energy compared to the inflationary cost trends in thermal power generation, IEEFA expects this trend to accelerate.

Figure 1.4: Global Electricity Sector Investment: 2000-2016 (US$bn)

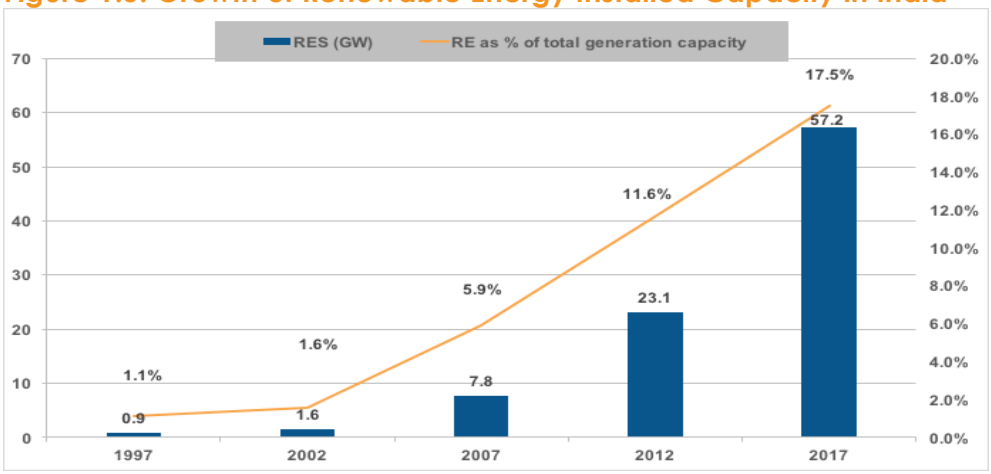


Source: IEA World Energy Investment, July 2017

IEEFA's focus on India reflects several factors. For starters, India is the second largest producer, consumer and importer of thermal coal globally, and its electricity market is already the third largest (overtaking Japan in 2013). In addition, India is currently tracking real economic growth of some 7% annually, making it the fastest growing major economy in the world. Finally, by the turn of this decade it will overtake China to have the largest population. Given all that, India, and the world, would be in dire straits if the country followed the traditional thermal power development path. But, leveraging the global renewable energy leadership of first Germany and more recently China, India has embarked on an aggressive effort to avoid overbuilding an electric system using outdated, expensive thermal power with all of its negative externalities. This will benefit India greatly, but it will also have enormous beneficial consequences for the world as a whole, accelerating the developing clean energy transition.

Figure 1.5 details the progressive uptake of non-hydro renewable energy capacity in India over the last two decades, reaching 57.2 GW by March 2017, a record 17.5% share of total on-grid installed capacity (but still just 7% of total generation). India's National Electricity Policy targets a fivefold expansion to 275 GW by 2027.

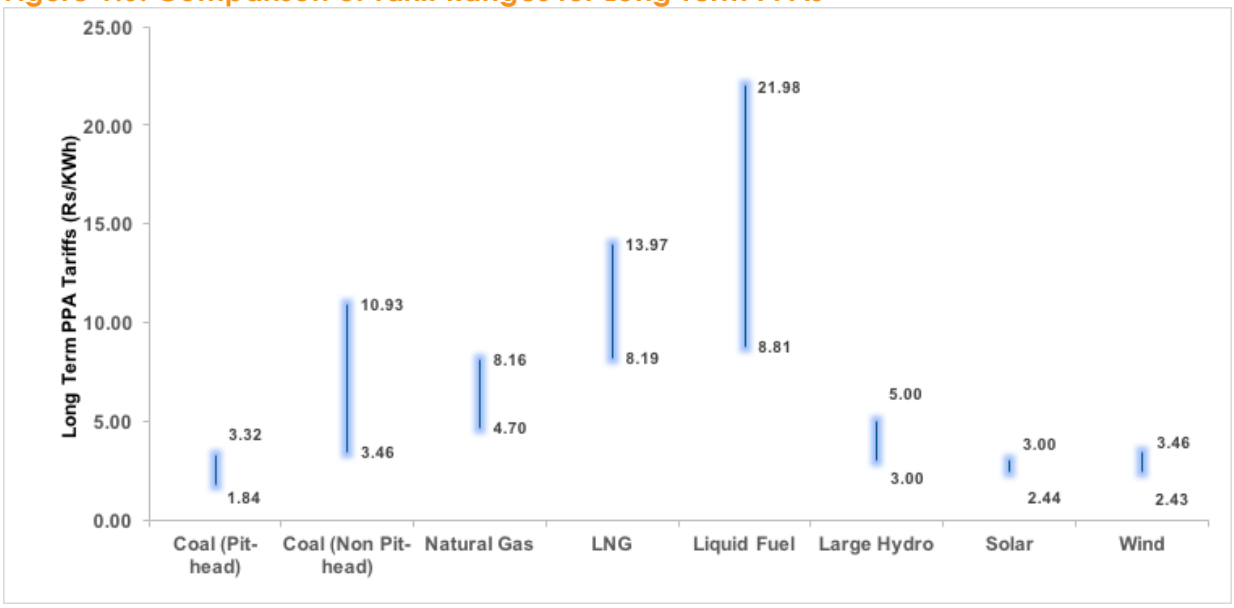
Figure 1.5: Growth of Renewable Energy Installed Capacity in India



Source: CEA, Fowind

Figure 1.6 details the range of tariffs currently applying to electricity generation in India by fuel source. While pithead domestic lignite-fired power is still the lowest cost source of supply, wind and solar are both now less expensive than any non-pithead coal power plant, and way below diesel and LNG power plants. Stranded asset risks are real and rising in India's thermal power sector.

Figure 1.6: Comparison of Tariff Ranges for Long Term PPAs



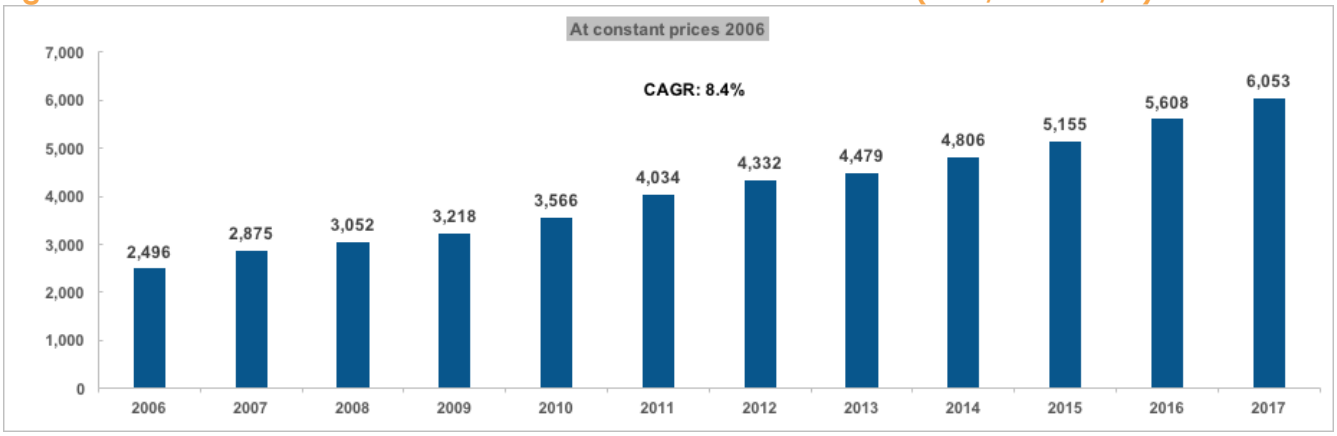
Source: Fowind, IEEFA calculations

2. Tamil Nadu: Economic Overview

Tamil Nadu is situated in the southern peninsula of the Indian subcontinent and is surrounded on the north by Andhra Pradesh and Karnataka, on the west by Kerala, to the east the Bay of Bengal (creating strong offshore wind opportunities) and the Indian Ocean to the south.

Tamil Nadu is India's second most economically competitive state based on criteria such as macroeconomic stability, financial, business and workers conditions, quality of life, infrastructure development and government factors. The state, which has one of the highest urbanisation rates in India, has been strikingly successful in reducing the percentage of people living below the poverty line, cutting this number from 45% in 1994 to 12% in 2012, and it continues to improve other human development-related indicators as well.[1] The state's per capita income in 2016 of Rs143,547 (US$2,213) is well above the India average (Figure 2.2) and third highest among large states.[2]

Figure 2.1: Real Gross State Domestic Product of Tamil Nadu in Billion Rs (2005/06-2016/17)



Source: Reserve Bank of India

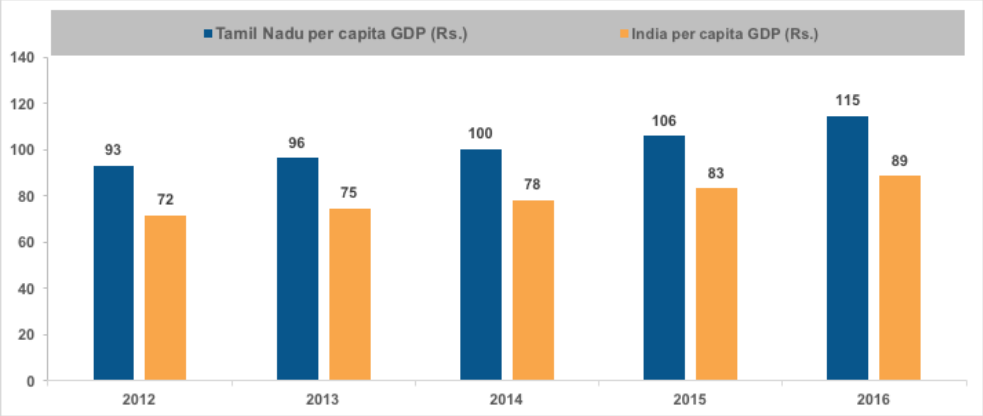
India's southernmost and fourth largest state by population is among the leaders for industries such as automobiles, components, cement, pharmaceuticals, textile products and chemicals. Traditionally known for knitting, the state's GDP grew at a compound average growth rate (CAGR) of 7.7% between 2007 to 2017.[3] The state's capital city of Chennai has been dubbed the "Detroit" of India, owing to its development as an auto production hub. The state has well-developed infrastructure in terms of rail, ports and air connectivity, and it continues to invest in highways and IT infrastructure to boost software and hardware exports.

The state had 16 operational special economic zones (SEZs) for Information Technology Enabled Services (ITeS) as of July 2016. Tamil Nadu has about 350,000 people directly employed in IT and ITeS companies, a figure that climbs to 750,000 when indirect employment is included. Tamil Nadu's proximity to East Asia has enabled Chennai to become an international IT and finance hub.

[1] http://documents.worldbank.org/curated/en/380971504177733539/pdf/119267-BRI-P157572-Tamil-Nadu-Poverty.pdf
[2] http://indiatoday.intoday.in/story/state-of-the-states-india-today-tamil-nadu-overall-most-improved/1/804507.html
[3] https://www.ibef.org/states/tamil-nadu.aspx

Tamil Nadu is consistently near the top of the list in terms of per capita GDP. This has implications for the state's existing and future energy intensity of activity, a factor we will discuss further (refer Section 10: IEEFA's Electricity Model for TN). Tamil Nadu's population is estimated at 72 million, 5.4% of India's estimated total of 1.34 billion people.

Figure 2.2: Tamil Nadu Vs India - GDP per Capita



Source: Reserve Bank of India, Department of Statistics India

TANGEDCO: Cutting Cross-Subsidises to Encourage Self-Generation

One key policy dilemma for Tamil Nadu's leaders and TANGEDCO stems from the provision of electricity for free[4] to the agricultural sector: 8% of the customer base by number, but 15% of electricity consumption by volume. This is a key social safety net for farmers hit with significant cost inflation and regularly depressed output prices, not to mention the vagaries of monsoonal floods and drought. However, it also means that TANGEDCO has to cross-subsidise this sector with revenues from the commercial and industrial (C&I) sector, which consume 46% of total electricity. However, the C&I sector can increasingly use rooftop solar and behind-the-meter generation to go off grid or at least materially reduce consumption in the face of high and rising tariffs (Rs7-8/kWh). TANGEDCO needs to reduce its AT&C losses, lower generation costs and leverage its positive demand growth profile to work with its C&I customers so as to avoid following the behind-the-meter generation trends increasingly evident in places like Germany, Australia and California. Making rural consumers focus on energy efficiency/restraint is also crucial, but it is not going to happen while there are no meters and electricity is provided free of charge.

This cross-subsidy is also a roadblock to the acceleration of residential rooftop solar. Residential customers pay just Rs3/kWh, well below TANGEDCO's production costs but still higher than the cost of rooftop self-generation (residential tariffs would need to exceed Rs4-5/kWh to justify rooftop solar currently). One way to resolve this dilemma would be to begin charging for electricity while at the same time depositing money into rural household bank accounts; this would break the link between the distribution company's losses and subsidised residential electricity while maintaining a clearly needed social safety net.

[4]TANGEDCO is compensated for free electricity to agricultural users by the Government of Tamil Nadu

3. Tamil Nadu Electricity Market

As of March 2017, the total on-grid installed capacity of Tamil Nadu was 30.1 GW, 9% of the total installed in India. Just like the rest of India, the state is heavily dependent on coal-fired generation for its power needs (45% of capacity, 69% of generation in 2016/17 – Figure 3.1). The installed thermal capacity in Tamil Nadu grew at average 10% annually since 2011. At the same time, and a key reason for this report, Tamil Nadu is the leader in India in terms of overall installed renewable energy capacity and generation, especially wind energy. TN's peak power supply deficit has constantly declined and FY2016/17 was the first year when it reported a zero peak power supply deficit.

Figure 3.1: Composition of Tamil Nadu's Electricity Sector (2016/17)

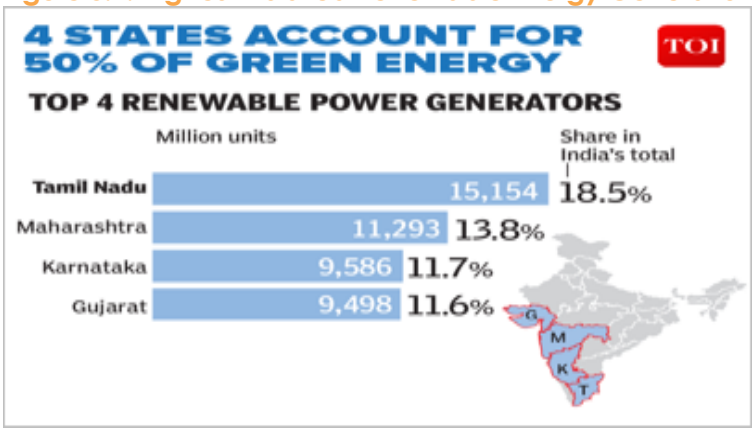
Source	Electricity market Composition 2016/17					
	Capacity		Generation		Capacity	YoY change
	GW	% of Total	TWh	% of Total	Utilisation	GW
Coal	13.4	45%	66.6	69%	62%	2.1
Gas	1.0	3%	2.2	2%	25%	0.0
Diesel	0.4	1%	0.9	1%	25%	0.0
Hydro	2.2	7%	2.4	2%	12%	0.0
Nuclear	2.4	8%	9.7	10%	57%	1.0
Renewable	10.6	35%	15.2	16%	18%	1.8
Total	**30.1**	**100%**	**97.0**	**100%**		**4.9**

Source: Central Electricity Authority of India, IEEFA estimates & calculations

A Leading Indian State for Renewables

At 15.15 terawatt-hours (TWh) generated from 10.6 GW of capacity, Tamil Nadu represented almost one fifth (18.5%) of India's total renewable energy generation in 2016/17. Tamil Nadu is also a leader in India with respect to household-level electrification, reported in the 2011 census at 93%, materially above the Indian average at the time of 67%.

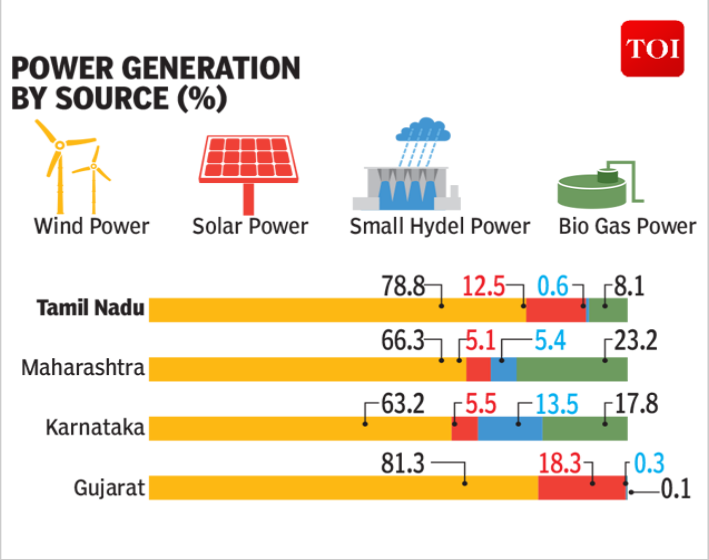
Figure 3.2: Highest Installed Renewable Energy Generation in 2016/17



Source: The Times of India

Of TN's 15.15 TWh of renewable energy production in 2016/17, 78.8% was generated by onshore wind, 12.5% from solar and 8.1% from biogas power (Figure 3.3). With ongoing production issues at the Kudankulam nuclear facility and significant coal availability limits due to the distance from the northeast Indian coal fields, renewables and hydro have both provided important grid diversification and peak demand support in 2017.[5]

Figure 3.3: Composition of Renewable Generation 2016/17 for Four Leading States of India



Source: The Times of India

Figure 3.4: Major Owners of Renewable Energy Capacity in Tamil Nadu

Major Wind Power Players in Tamil Nadu		Major Solar Power Players in Tamil Nadu	
Company	**Existing Capacity (MW)**	**Company**	**Existing Capacity (MW)**
Muppandal Wind farm	1,500	Adani Power	648
Orient Green (Chennai)	250	Greenko	150
Tata Power Renewable Energy	99	NLCIL	168
CLP India (HK)	99		
Company	**Pipelined Capacity (MW)**	**Company**	**Pipelined Capacity (MW)**
NLCIL	500	NLCIL	709
Sembcorp (Singapore)	250	TANGEDCO	500
Siemens Gamesa	200	NPCL	50

Source: Company Reports, IEEFA calculations

Note: IEEFA could find absolutely no details about Muppandal wind farm, nor almost any of the reported 7.9 GW of wind farms built and owned by private industry across TN during the last 30 years to access accelerated depreciation and other tax allowances. We note the operating data suggests a very low 17.4% average utilisation rate on renewables in TN in 2016/17, consistent with the outdated technology and near end-of-life nature of most existing wind farms. This suggests there is enormous potential for repowering, which could increase output tenfold (refer Section 6).

[5] https://energy.economictimes.indiatimes.com/news/coal/shortage-of-coal-gives-tamil-nadu-power-sector-a-jolt/61233627

Structure of Tamil Nadu's Electricity Board

In 2010 the Tamil Nadu Electricity Board (TNEB) was restructured into the TNEB Ltd as a holding company, plus two wholly-owned subsidiaries; Tamil Nadu Generation and Distribution Corp. (TANGEDCO); and Tamil Nadu Transmission Corp. (TANTRANSCO), This was consistent with The Electricity Act 2003, which stipulated the unbundling of state electricity boards.[6]

As of March 2017, TANGEDCO owns and operates 2.2 GW of hydroelectricity capacity, plus 4.3 GW of coal-fired power and 0.5 GW of gas power; it also has contracts for 6.0 GW of central government-owned thermal power generation and 5.6 GW of privately owned thermal power plants. As of March 2017, the distribution company has contracts for 10.6 GW of renewable energy capacity (7.9 GW wind, 1.7 GW solar, 0.2 GW of biomass and 0.7 GW from biomass co-generation plants).

Interstate Green Power Corridor

The development of India's interstate green power corridor should prove beneficial to TANGEDCO and renewable energy developers in Tamil Nadu (where 2,000 MW is currently being built) and elsewhere across the country. Union Coal Minister Piyush Goyal told the Lok Sabha (India's lower House of Parliament) that work on the Rs11,369 crore corridor had started and that it should be operational by May 2019.

In the light of many states falling short of meeting their renewable power obligation targets, Tamil Nadu's surplus renewable power generation could be in high demand in the national market, particularly if the central government is able to better enforce the country's renewable purchase obligation (RPO). India's RPO refers to the obligation of certain entities either to buy electricity generated by specified green sources, or in lieu of that, buy renewable energy certificates (RECs) from the market.

In TN, the green corridor starts from Tuticorin district and ends in Kancheepuram district.

The interstate transmission network scheme is being implemented by the Power Grid Corporation of India Limited (PGCIL). About 30% (Rs3,410 crore) of the cost will be in the form of equity and 70% will be concessional loans (Rs5,203 crore from German-based KfW and Rs2,756 crore from the Asian Development Bank).[7] To incentivise optimal siting of renewable energy infrastructure projects in areas with the best wind and solar resources, the central government in December 2017 extended its waiver of interstate transmission system charges and losses for 25 years for all new renewable energy projects commissioned by March 2019. This is a very positive policy support for renewables with a clear end-date.[8]

Along with investment in distributed battery storage, demand response management technologies, better diversification of electricity generation capacity across a range of fuel types, solar thermal power and pumped hydro storage (e.g. 500 MW at Kundah), interstate grid connectivity will each play a key enabling role to accommodate progressively higher market share of variable renewable energy sources.

[6] https://www.tangedco.gov.in/profile.html
[7] http://energy.economictimes.indiatimes.com/news/renewable/tangedco-set-to-tap-15000-mw-green-power-in-two-years/59832759
[8] https://mercomindia.com/cerc-waives-ists-for-solar-projects/

4. Thermal Power Generation

Coal Power: An Expensive Option for TN

Tamil Nadu currently has 14.1 GW of coal-fired power capacity operational (Figure 4.1). The state Discom TANGEDCO owns and operates 4.77 GW while NLC India Ltd has 3.99 GW of mainly mine-mouth lignite-fired power plants. NTPC Ltd and Infrastructure Leasing & Financial Services Limited (IL&FS) are the other major coal plant operators.

Figure 4.1: Major Coal Fired Power Plant Owners in Tamil Nadu (MW)

Sponsor	Capacity Owned (MW)
TANGEDCO	4,320
NLCIL	3,990
NTPC	1,500
IL&FS	1,200
Others	3,066
Total	**14,076**

Source: Global Coal Plant Tracker, accessed January 2018

Because of the remote location of Tamil Nadu relative to the thermal coal fields of central and northeast India, which are over 1,650 kilometres (km) away, even domestic thermal coal-fired power expensive in TN. Rail costs of US$30-40/t over this distance are prohibitive, particularly given the high ash and hence low energy content of Indian coal (averaging just 3,000-4,000 kcal).

Figure 4.2: Coal Transport's Impact on Electricity Prices

Source: BNEF

While coastal barges from Odisha cost less than rail over this distance, it is still an expensive option. While Indian mine-mouth coal plants have tariffs of ~Rs2-4/kWh, tariffs at the four Tamil Nadu coal-fired power plant tariffs we identified were all set at Rs5.23/kWh,[9] and interstate thermal power imports into Tamil Nadu average Rs4.91/kWh (under long-term contracts with players like Sembcorp Gayatri Power Ltd's 2.64 GW coal plant at Krishnapatnam, Andhra Pradesh[10])—all a clear 50-100% tariff premium to reflect the extra coal transportation costs. These expensive coal power plants face curtailment and/or downward tariff revisions if TANGEDCO is going to be able to reduce its unsustainable operating losses (refer Section 9).

IEEFA calculates the average Tamil Nadu coal-fired power plant operated at 62% in 2016/17 (Figure 3.1). While this is higher than the national thermal average of 57%, it is well below design targets of 75-85%, the optimal utilisation rate. The fact that utilisation rates have hit a 10-year low is a clear signal of overbuilding, reflecting overestimation of demand growth and an underestimation of the take-up of increasingly low cost renewable energy alternatives.

While existing mine-mouth coal-fired power is still the low-cost generation source in India (ignoring external costs like water, coal ash and air pollution), the massive extra freight cost in Tamil Nadu stands in stark contrast to wind and solar tariffs now readily available at below Rs3/kWh, even when taking the higher financial risk premium associated with Tamil Nadu's historically poor regulatory framework and the financial distress of its distribution company into account. Combined with weak and declining utilisation rates for coal-fired power plants, this begs the question of who would finance the 20 GW pipeline of proposed new coal plants across TN.

Coal Power Plants: TANGEDCO

TANGEDCO, Tamil Nadu's vertically integrated state distribution company owns 4.32 GW of coal-fired power generation capacity. Of these 1.89 GW will exceed 35 years of age by 2027. The company's main TN coal plants include:

- The 1.05 GW Tuticorin Thermal Power Station, a subcritical coastal plant using seaborne coal imported through the port of Thoothukudi (commissioned 1979-1991);
- The 1.44 GW Mettur Thermal Power Station (commissioned 1987-2013), an inland location requiring coal to move by rail to ports in India's Northeast for coastal shipping to Ennore Port in TN before being reloaded on rail wagons to get to Mettur (600 MW is supercritical, the 840 MW is outdated subcritical technology);
- The 1.83 GW North Chennai Thermal Power Station located at the Ennore Port and commissioned 1994-2014 (all outdated subcritical technology).

The 450 MW Ennore Thermal Power Station located at the Ennore Port was commissioned 1970-1975 and after more than 40 years of operation was decommissioned in March 2017[11]. The site is being used for a replacement supercritical thermal power plant of 660 MW that is currently under construction and due for commissioning 2018/19.

[9] http://cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-03.pdf
[10] http://energy.economictimes.indiatimes.com/news/power/tamil-nadu-power-utility-to-save-rs-2000-crore-per-year-in-discounts/59649951
[11] https://www.sourcewatch.org/index.php/Ennore_Thermal_Power_Station

TANGEDCO has proposed the following coal-fired power plant expansions:

- The 1.32 GW Ennore SEZ Supercritical Thermal Power plant is under construction and due for commissioning in 2018, but it is likely to be delayed several years;
- The 800 MW North Chennai Thermal Power Station Stage III is under permitting and reported as due for commissioning in 2019/20, albeit this looks likely to have slipped several years as construction does not appear to have started;
- The 1,600 MW supercritical Uppur Thermal Project Stage III is permitted and was due for commissioning in 2019/20, but is being held up by a legal dispute over land acquisition;[12]
- TANGEDCO was reported in 2016 as considering a 500 MW expansion of the Mettur Thermal Power Station Stage III, but we exclude this from Figure 4.3 (below) as it is not permitted yet, and it would be entirely surplus to Tamil Nadu needs; and
- A 1.32 GW supercritical thermal power plant at Udangudi, proposed in December 2017, with BHEL being awarded the EPC contract.[13]

TANGEDCO operates 2.4 GW of hydroelectricity capacity across Tamil Nadu. TANGEDCO states that it has fully exploited the hydroelectric potential available in the state, but in 2015 proposed to build the 500 MW Kundah Pumped Storage Hydroelectric facility in the Nilgiris Hills of TN to add peaking capacity using two existing reservoirs due for commissioning 2021[14] [15] plus small run-of-river hydro projects with a combined capacity of 110 MW.[16] TANGEDCO owns almost no wind or solar assets.

Coal Power Plants: NTPC Ltd

NTPC Ltd is a Bombay Stock Exchange listed power generation company; it is 63% owned by the central government. It operates over 50 GW of total power capacity across India (over 44 GW of this is coal-fired) and generates some 25% of all of India's electricity needs. NTPC Ltd is one of the 10 largest coal-fired power generation companies globally. However, NTPC Ltd also is playing an increasingly key role in transforming the Indian electricity sector, with plans to build or facilitate third party renewable energy infrastructure totalling 25 GW by 2022. As of January 2018, NTPC owns 1.72 GW of fully commissioned renewable infrastructure projects (0.87 GW solar, 0.05 GW wind and 0.8 GW of hydro capacity).

In Tamil Nadu, NTPC Ltd operates a single coal plant, the 1.5 GW Vallur Thermal Power Station (an NTPC joint venture with TANGEDCO) located at the Ennore Port and commissioned 2010-2013 using outdated subcritical technology running on coal shipped interstate from West Bengal and then moved by conveyor-belt from the adjoining Ennore port.

[12] http://www.thehindu.com/news/national/tamil-nadu/uppur-thermal-project-yet-to-get-off-the-ground/article18495668.ece
[13] https://energy.economictimes.indiatimes.com/news/power/bhel-bags-rs-7300-crore-contract-for-supercritical-power-project-in-tamil-nadu/62082160
[14] https://www.thefreelibrary.com/Kundah+Pumped+Storage+Hydro+Electric+Project.-a0400486838
[15] http://www.thehindubusinessline.com/todays-paper/tp-economy/tneb-lines-up-2500-mw-projects/article1662136.ece
[16] https://www.tangedco.gov.in/generation.html

Lignite Coal Power Plants: NLC India Ltd

NLC India Limited ((NLCIL) formerly Neyveli Lignite Corporation) is a 'Navratna' profit making, government of India enterprise that since 1962 has been engaged in mining of lignite and generating power through five lignite-fuelled power plants with a combined capacity of 3.24 GW and 1.0 GW of conventional coal-fired power plants. All of this capacity is based in Tamil Nadu, save a small 250 MW lignite mine-mouth power plant in Rajasthan.

NLCIL operates four open cut mines with a combined capacity of 30.6 Mtpa; of this 28.5Mtpa is in Tamil Nadu with the balance of 2 Mtpa in Rajasthan. The enterprise has plans to expand to a total of 57 Mtpa of lignite mining capacity (plus 31 Mtpa of new thermal coal capacity in Odisha).[17] Total lignite reserves in India are estimated at 65,000 Mt, of which 80% is in TN.

Associated with its plans to treble total coal production, NLCIL also plans to treble its non-pithead thermal power generation capacity by 2025.

In Tamil Nadu, NLC Ltd currently operates 3.99 GW of lignite and coal-fired power plants:

- NLCIL's oldest lignite power facility is the 0.6 GW Neyveli Thermal Power Station I (TPS-I), commissioned progressively over 1962-1970, this facility is operating well beyond its design life and is over-due for closure (a plant failure killing three staff in 2014[18]);
- Neyveli Thermal Power Station I Expansion added 0.42 GW (commissioned 2002-2003);
- The 1.47 GW Neyveli Thermal Power Station II ((TPS-II) 7 units commissioned 1986-1993);
- The 0.5 GW Neyveli Thermal Power Station II expansion (commissioned in 2015); and
- The 1.0 GW coal-fired Tuticorin NTPL Thermal Power Station (commissioned 1979-1991),

NLCIL has the Neyveli New Thermal Power Station (NNTPS) of 1.0 GW lignite power capacity due for commissioning in 2018/19, as a replacement for the 600 MW TPS-I. Likewise, NLC has flagged that its 1.47 GW TPS-II facility is approaching the end of its 30-year design life and is due for progressive replacement (Figure 4.4 references 1.26 GW of this is >35 years by 2027).

Beyond this, NLCIL has large coal-fired power plant expansion plans in TN, but we have not included these in Figure 4.3 as both proposals are in the pre-permitting stage and in IEEFA's view entirely surplus to Tamil Nadu's requirements barring the cancellation of some of the more advanced, but much more expensive, import coal plant proposals detailed above:

- the 1.32 GW lignite TPS-II Second Expansion – Phase I (proposed for completion 2022); and
- the 1.32 GW lignite TPS-II Second Expansion – Phase II (proposed for completion 2024).[19]

October 2017 saw NLCIL cancel its long proposed 3.96 GW Sirkali coal-fired power plant, stating that coal transportation costs would be prohibitively expensive, and required a tariff of at least Rs5.50/kWh vs pithead lignite at just Rs4/kWh[20] and new renewables at Rs2-4/kWh.[21]

Like NTPC Ltd, NLCIL is diversifying into renewable energy, with 140 MW of solar at Neyveli, TN and 51 MW of wind at Tirunelveli, TN installed as at January 2018, but with an ambitious target

[17] http://events.nlcindia.com/ns/
[18] http://www.thehindu.com/news/one-killed-six-injured-in-nlc-steam-pipeline-burst/article6029253.ece
[19] https://www.nlcindia.com/new_website/nlc_corporate_plan.pdf
[20] http://cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-11.pdf (Page 33-41)
[21] http://www.thehindu.com/todays-paper/tp-national/tp-tamilnadu/nlcil-to-make-up-for-shelving-sirkazhi-project/article19825618.ece

to expand total renewable energy capacity to 4.2 GW by 2020.[22] In July 2017 NLCIL bid for the entire 1.5 GW and won a total of 449 MW in the latest Tamil Nadu tender of new solar at Rs3.47/kWh[23] and has also participated in Tamil Nadu's latest 500 MW wind tender.

New Coal Plant Pipeline for TN

Figure 4.3 collates all the new coal-fired power plants under construction—six new plants with a combined capacity of 4.47 GW. In addition, another 5.04 GW of coal plants in Tamil Nadu have progressed through permitting and proponents are still considering construction. Behind these 9.5 GW of new coal-fired developments are another 6.9 GW that have been announced plus 6.1 GW in essentially the late planning stages—22.5 GW in total. In IEEFA's estimation, these proposals will struggle to attain financial close given the collapsing utilisation rates across TN and India generally.

In Section 10 IEEFA presemts our model of Tamil Nadu electricity sector demand and supply over the coming decade to 2026/27. As of March 2017, existing coal-fired power capacity in Tamil Nadu was 13.4 GW (Figure 3.1). In IEEFA's model, we include the addition of 4.47 GW of new coal plants already under construction (Figure 4.3) plus assume half of the 5.04 GW of permitted new plants proceed. Against this, we deduct all the 3.75 GW of coal plants that will exceed 35 years of age by 2026/27 (Figure 4.4). This gives an estimated 16.6 GW of coal-fired power capacity by March 2027 in operation in Tamil Nadu, per the following calculation:

So, 13.40 GW + 4.47 GW + (50% of 5.04 GW) – 3.75 GW = 16.60 GW

March'17 + Construction + half of Permitted - end of life = March'27

The October 2017 cancelation of NLCIL's Sirkali import coal plant is an economically sensible decision, and one IEEFA expects to be repeated many times in the next few years, if stranded assets are to be avoided.

Figure 4.3: Major Coal-Fired Power Plant Pipeline in Tamil Nadu (MW)

Under Construction Coal-fired plants	Sponsors	Fuel	Capacity (MW)
Ennore SEZ Super Critical Thermal Power Project (Vayalur)	TANGEDCO	Imported thermal coal	1,320
Ennore Thermal Power Station	TANGEDCO	Imported thermal coal	660
Nagai Nagapattinam Power Project	KVK Energy & Infra	Thermal coal	300
New Neyveli Thermal Power Station	NLCIL	Lignite	1,000
SEPC Tuticorin power station	SEPC Power	Imported thermal coal	525
Tuticorin power station (Ind-Barath)	Ind-Bharath Power	Thermal coal	660
Sub-total			**4,465**
Permitted Coal-fired plants	**Sponsors**		**Capacity**
North Chennai Thermal Power Project Stage III	TANGEDCO	Thermal coal	800
Ottapidaram power station	KU Thermal Power	Thermal coal	1,320
Uppur power station	TANGEDCO	Thermal coal	1,600
Udangudi Super Critical Thermal Power Project	TANGEDCO	Thermal coal	1,320
Sub-total			**5,040**
Grand Total			**9,505**

Source: Global Coal Plant Tracker (GCPT) database, IEEFA calculations

[22] http://events.nlcindia.com/ns/RenewableTopic.aspx

[23] http://economictimes.indiatimes.com/industry/energy/power/nlc-biggest-winner-in-1500-mw-tn-solar-auction/articleshow/59415197.cms?utm_source=WAPusers&utm_medium=whatsappshare&utm_campaign=socialsharebutton&from=mdr

Coal Plant Retirements for TN

IEEFA's Ten Year Electricity Model (refer Section 10) starts with the calculation that Tamil Nadu's coal-fired power plant fleet operated at an average capacity utilisation of 61.6% in 2016/17. Even with a dramatically scaled back coal fleet expansion plan, the coal sector's utilisation rate by 2026/27 will average below 40% absent a government policy decision to enforce end-of-life coal plant closures by regulatory edict. The intensifying pollution pressures across India provide a clear community imperative for this public policy move, and it is interesting to see that the economic argument here aligns with public interest.

Closing end-of-life plants that are increasingly less thermally efficient, more expensive to maintain, heavily polluting and increasingly a corporate safety risk (witness three workers killed in 2014 at Neyveli TPS-I) would reduce the excess capacity in the Tamil Nadu coal-fired power sector and allow the remaining coal-fired power fleet to operate at higher capacity utilisation rates: a win-win outcome. A progressive implementation and enforcement of the Central Pollution Control Board legislation first proposed in 2015 to take effect from December 2017[24] would improve the coal sector's economics, a critically important requirement given the unending downward pressure on wholesale electricity tariffs that is under way from ever-more competitive and zero marginal cost wind and solar projects.

TANGEDCO's 450 MW subcritical Ennore Thermal Power Station was commissioned 1970-1975 and after more than 40 years of operation was decommissioned in March 2017. The site is being used for a replacement supercritical thermal power plant of 660 MW that is currently under construction.

NLCIL has the Neyveli New Thermal Power Station (NNTPS) of 1.0 GW lignite power capacity due for commissioning in 2018/19, as a replacement for the beyond end-of-life subcritical 600 MW Neyveli Thermal Power Station I (TPS-I).

Likewise, NLCIL's 2015-2025 corporate plan has flagged that its 1.47 GW TPS-II facility is also approaching the end of its 30-year design life and is due for progressive replacement.

IEEFA's model assumes all of the 3.75 GW end-of-life closures required (as per Figure 4.4) take effect by 2026/27; accelerating closures would raise utilisation rates and help consumers.

Figure 4.4: Coal-Fired Power Plants Pre-1993 in Tamil Nadu (MW)

Plant	Sponsor	Capacity (MW)
Mettur Thermal Power Station	TANGEDCO	840
Neyveli Thermal Power Station I	NLCIL	600
Neyveli Thermal Power Station II	NLCIL	1,260
Tuticorin Thermal Power Station	TANGEDCO	1,050
Total		**3,750**

Source: Global Coal Plant Tracker

[24] http://www.news18.com/news/india/as-thermal-power-plants-miss-clean-up-deadline-environment-ministry-mulls-over-new-time-frame-1599747.html

Ultra Mega Power Plants (UMPP)

The previous Indian Government proposed to build a series of 16 UMPPs of 4,000 MW of capacity each. A decade on, this UMPP program has been re-evaluated, downsized and deferred. The first two projects became operational but have proven problematic, reflecting excessive financial leverage and irrationally low tariff bidding, particularly in terms of failure to adequately price in / hedge currency and commodity price risk for imported coal.[25]

Tata Power's Mundra based 4.0 GW UMPP using imported coal reported a record loss in the June 2017 quarter and the company has been repeatedly reported as offering the US$4bn plant's equity for sale at a token Rs1,[26] implying a US$1bn equity write-off. Adani Power's nearby 4.6 GW Mundra import coal-fired power plant is similarly for sale for Rs1 following losses over the last seven years.

In February 2015 Finance Minister Arun Jaitley announced plans for a plug-and-play model for big-ticket infrastructure projects in his budget speech, but beyond this the UMPP scheme has failed to gain private sector backing and has been largely overtaken by the electricity sector's rapid diversification into ever-cheaper, faster to build renewable energy infrastructure.

Cheyyur UMPP

In January 2015, Piyush Goyal, then minister of power for the Government of India, terminated the bid process for the proposed 4,000 MW import coal-fired Cheyyur UMMP. The reason for terminating the bidding was that seven out of eight applicants pulled out of the process citing their inability to secure financing for the project. Consistent with a report by IEEFA in 2015, the plant would undoubtedly put upward pressure on electricity prices with a tariff requirement of Rs4.90/kWh (US$75/MWh) in the first year of operation and a levelised price of Rs5.95/kWh (US$91/MWh) over the plant's operating life.[27] The estimated tariff does not include potentially significant environmental liabilities. Neither does it factor in any cost overruns due to likely delays surrounding issues such as land acquisitions.

In May 2017 Goyal announced new plans to try to resurrect this long-delayed proposal, saying the energy department of Tamil Nadu had agreed to the central government's request to change the project's fuel source from imported to domestic coal.[28] In light of the announcement of October 2017 for the cancelation of NLCIL's Sirkali import coal plant as economically unviable, IEEFA reiterates that the Cheyyur UMPP likely will remain nothing more than a stranded asset proposal. In February 2018 Coal Minister Piyush Goyal suggested India should aspire to a 50% renewables by 2030 target, a position IEEFA would strongly second.

[25] https://www.bloombergquint.com/business/2017/08/29/governments-plan-of-setting-up-five-ultra-mega-power-projects-in-limbo-

[26] http://www.business-standard.com/article/companies/post-gujarat-elections-spotlight-is-back-on-tata-adani-mundra-plants-117123000743_1.html

[27] IEEFA, *Cheyyur UMPP: Financial Plan Will Make Electricity Unaffordable*, May 2015

[28] https://energy.economictimes.indiatimes.com/news/power/cheyyur-umpp-to-be-built-on-domestic-coal-piyush-goyal/58750656

Gas-Fired Power Generation

Declining domestic natural gas production has been an ongoing problem in India this decade, with regulated domestic pricing set well below import price parity. While providing a favourable cost outcome for gas users, this also has had the effect of limiting new domestic supply by disincentivising new exploration. As a result, India is set to become increasingly dependent on liquid natural gas (LNG) imports. Notwithstanding the one-third price decline seen across Asia in LNG in the last 3-4 years, it is still a high-cost fuel source for electricity generation, best suited for supplying peaking requirements. While India has 25 GW of gas-fired generation capacity already online, the average utilisation rate of just 20-25% in 2016/17 is indicative of the uncompetitiveness of LNG as a baseload electricity source. With the near doubling of LNG import prices over 2017/18 from recent troughs, this uncompetitiveness is set to worsen, particularly relative to the ongoing deflation in renewables.

The rising share of intermittent renewable generation could provide India an opportunity for wholesale pricing reform to better incentivise power supply in periods of peak demand to maintain system balance and avoid disruptive load-shedding.

TN currently operates 1 GW of gas-fired power generation capacity (3% of capacity, 2% of electricity production) across seven facilities. There is a single 980 MW gas-fired power plant expansion under way at TN's largest gas generation facility of 330 MW capacity, privately owned by PPN Power Generating Company Private Limited.[29] With environmental clearances received in 2011 the company reports an EPC contract was awarded to Larsen & Toubro Ltd. However, after six years delay and no sign of progress, this proposal is likely to remain a stranded asset undercut by the increasing cost-competitiveness of renewable energy in India. We assume this capacity expansion is not completed in our TN state electricity model (refer Section 10).

We note that the Indian Oil Corp. is due to bring online a US$800m, 5 Mtpa LNG import facility in 2018 at Ennore.[30] [31] While primarily built to supply gas feedstock for the fertilizer sector, this will also provide an alternative source of imported gas for the electricity sector.

[29] http://www.ppnpower.com/Expansion.html
[30] http://www.thehindu.com/news/cities/chennai/IOC's-LNG-terminal-will-be-ready-in-2018/article14507509.ece
[31] https://www.iocl.com/Products/NaturalGas.aspx

5. Nuclear Power Generation

Nuclear Power Capacity: India

The draft national energy plan by the Government of India's (GoI) think-tank, NITI Aayog, targets an entirely unfeasible 60 GW of nuclear capacity installation by 2030, which would increase the current capacity of 6.8 GW almost tenfold.[32] Piyush Goyal, the former energy minister, in August 2017 downgraded the expectations due to the high cost, long construction lead-times and India's dependence on foreign-sourced uranium.[33] India's scope for domestic production of uranium has increased in recent years.[34]

Nuclear Power Capacity: Tamil Nadu

Tamil Nadu has 2.47 GW of installed capacity across two plants forms 36% of India's total installed nuclear capacity. Construction of the first unit began in 2002 with commissioning in 2013. 2016 saw the inauguration of the 1,000 MW Unit 2 of the Kudankulam nuclear plant which at 2 GW made it the largest generating capacity nuclear plant in India. However, it has continued to have a controversial history, with numerous delays and protests impending its progress, plus breakdowns and extended annual repairs at time of peak power need.[35]

The 2 GW Kudankulam plant is owned by the Nuclear Power Corporation of India Ltd and was built with Russian technology and financing. Construction of Units 3&4, both at 1,000 MW, began in mid-2017,[36] with a reported total construction cost of Rs399bn (US$6.1bn),[37] more than double the cost of Units 1&2. Kudankulam is scheduled to have six VVER-1000 pressurised water reactors built in collaboration with Atomstroyexport/ROSATOM State Atomic Energy Corporation, the Russian state company, with a total installed capacity of 6,000 MW of electricity.[38] IEEFA assumes that with the usual cost and timetable blowouts, only one of these units will be commissioned in the coming decade.

TANGEDCO is reported to be paying only around Rs4.29/kWh for power from the Kudankulam 1&2 nuclear plants, [39][40] implying that there are massive funding subsidies in place within the generation entity supplying TN with nuclear power. TN receives just under half of the generation from Kudankulam, with the balance exported interstate to Karataka, AP, Kerala and Puducherry.

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[32] http://niti.gov.in/writereaddata/files/new_initiatives/NEP-ID_27.06.2017.pdf
[33] http://www.hindustantimes.com/india-news/india-to-add-7k-mw-nuclear-power-capacity-piyush-goyal/story-XkL2i8gIIgZA73ns7uE46L.html
[34] http://www.ndtv.com/india-news/india-is-uranium-rich-country-nuclear-chief-dr-sekhar-basu-1748499
[35] https://energy.economictimes.indiatimes.com/news/coal/shortage-of-coal-gives-tamil-nadu-power-sector-a-jolt/61233627
[36] https://energy.economictimes.indiatimes.com/news/power/kudankulam-nuclear-plants-second-unit-may-restart-mid-november/61394743
[37] https://www.ndtv.com/india-news/work-begins-at-kudankulam-nuclear-power-plants-unit-3-1718652
[38] https://www.reuters.com/article/us-russia-economic-forum-india-nuclear/russia-signs-deal-to-expand-indias-kudankulam-nuclear-plant-idUSKBN18S5UL
[39] https://timesofindia.indiatimes.com/city/chennai/Kudankulam-power-to-cost-4-29/unit/articleshow/45712143.cms
[40] http://energy.economictimes.indiatimes.com/news/power/tamil-nadu-power-utility-to-save-rs-2000-crore-per-year-in-discounts/59649951

Nuclear Power: International Lessons

IEEFA has long argued that nuclear is an expensive electricity option for India, with 10-15 year construction time frames making it impractical relative to the 5-6% annual electricity demand growth that requires continual expansion of new capacity. With tariff deflation and construction times of 1-2 years, wind and solar are far lower risk options. Built with appropriate safety standards, nuclear can play an incremental role and does provide diversification of India's zero-emissions generation capacity. We detail several recent international nuclear experiences as a reminder of the community and financial risks involved with nuclear power.

U.S. Nuclear Power Plants: Extreme Time & Cost Blowouts

The two American projects majority owned by Southern & SCANA (two big utilities based in Georgia & South Carolina, respectively) have faced ongoing cost blowouts, construction related problems and new safety requirements from the American regulators.[41]

SCANA spent a decade trying to build the Summer Nuclear Generating Station in South Carolina, This plant has one Westinghouse 3-loop Pressurized Water Reactor in operation since 1984 and was building two new 1,100 MW Westinghouse AP1000 units scheduled to go into service in 2020. Ongoing construction problems only got worse in March 2017 when designer and contractor Westinghouse filed for bankruptcy. Originally slated to cost US$10bn, the cost estimate blew out to US$25bn. In July 2017, SCANA decided to stop construction of the half-built reactors.[42]

Since 1989 Southern Company has operated the Vogtle nuclear facility in Georgia with units 1 & 2 having a combined capacity of 2.4 GW. Southern commenced planning units 3 & 4 in 2006 using Westinghouse AP1000 technology with an initial budget expectation of US$14.5bn (itself 60% higher than the final cost of the first two units of US$8.9bn).[43] This was among the first new nuclear developments in the U.S. since the 1979 Three Mile Island accident. The Department of Energy provided a US$8bn loan subsidy. Construction commenced in 2013 and completion was due in 2016/17—but has now been delayed five years to 2021/22. In 2017 the construction manager, the Shaw Group, was replaced by Bechtel and the expected cost was estimated to have increased to US$25bn.[44] Additional cost increases and further delays can be expected before the two new nuclear plants are completed.

Finland's Olkiluoto 3 Bankrupted France's Areva

Areva's EPR reactor at Olkiluoto 3 broke ground in 2005 and was scheduled for completion in 2009; it is now a decade behind schedule. The expected cost of the Olkiluoto European Pressurised Reactor (EPR) has risen significantly with the last public estimate of €8.5bn being almost two-and-a-half times the original €3.2bn. Finnish utility TVO and French state-owned Areva are mired in multibillion-Euro litigation over responsibility for cost increases at Olkiluoto. Areva has already recorded a €3.9bn impairment on Olkiluoto, forcing a €5bn bailout by investors including the French state, and leading to Areva's merger with French utility EDF.

[41] https://en.wikipedia.org/wiki/Virgil_C._Summer_Nuclear_Generating_Station
[42] https://www.bloomberg.com/news/articles/2017-07-31/scana-to-cease-construction-of-two-reactors-in-south-carolina
[43] http://chronicle.augusta.com/business/2009-11-22/vogtle-lays-groundwork-first-us-reactors-decades
[44] https://www.greentechmedia.com/articles/read/georgia-power-vogtle-nuclear-plant-hearings#gs.p1TQfuk

Toshiba of Japan Nearly Sunk by Its Westinghouse Acquisition

Toshiba's Westinghouse Electric U.S. held the contract to supply reactors for the Summer and Vogtle projects. February 2017 saw Toshiba announce a US$6.1bn write-down for the two American projects.[45] This culminated in Toshiba selling Westinghouse Electric for just US$4.6bn to Brookfield of Canada in January 2018.[46] In contrast, the Carlyle Group argues that absent massive government subsidies, nuclear use in the U.S. will end in the next few decades.[47] The shareholder wealth destruction for each of Toshiba, Southern Company and SCANA over 2016/17 makes a mockery of the June 2017 deal by India's Prime Minister Narendra Modi with U.S. President Donald Trump for the U.S. Export-Import Bank to provide a US$8bn subsidised loan in return for India importing Westinghouse technology.[48] Any deal remains problematic because in India any nuclear equipment supplier is liable in case of an accident. This is different from the global norm where only the plant operators are liable to damages caused.

U.K. Hinkley Point Nuclear Project: Time & Cost Blowouts

The U.K.'s government-sponsored 3.2 GW Hinkley Point C project is another over-budget and already-delayed nuclear white elephant being built by EDF supported by subsidised Chinese banks. IEEFA's October 2017 report highlights the risk in building a new nuclear plant with the same untested EPR design now a decade behind schedule at Okiluoto. The estimated cost of Hinkley Point is £19.6bn and completion is said to be in 2025. But given the actual experience at Okiluoto it is impossible to truly know when the plant will be finished and how much it ultimately will cost. EDF will be paid £92.50/MWh for the power from Hinkley Point. Although this PPA insulates EDF from falling wholesale power prices, it does not protect it if the plant generates less power than EDF now claims. This is a reasonable possibility given that renewable power prices keep falling. IEEFA estimates the public subsidy at £30bn.[49]

Fukushima: US$200bn Clean-up Bill

Japan's optimism for meeting its target for nuclear to provide one-fifth of its electricity by 2030 comes amidst ongoing community protests about both safety concerns and the government's decision to use taxpayer money for decontaminating areas in Fukushima affected by radioactive fallout in March 2011. The estimated clean-up cost of ¥21.5 trillion /US$200bn is expected to be passed on to consumers in the form higher electricity prices, an attempt to bail out TEPCO, which was largely responsible for the nuclear disaster.[50] The catastrophe has not only posed serious questions on the safety-related risks of nuclear power, but also has proven to be financially severe. TEPCO's shareholders have seen 80% of their capital destroyed since the disaster, a spectacular hit on its valuation particularly when considered against the near-doubling of the Japanese stock market over the same period.[51]

[45] https://en.wikipedia.org/wiki/Virgil_C._Summer_Nuclear_Generating_Station
[46] https://www.reuters.com/article/us-westinghouse-m-a-brookfieldbusinesspa/brookfield-business-partners-to-buy-westinghouse-for-4-6-billion-idUSKBN1ET1MQ
[47] http://www.bloomberg.com/news/articles/2016-10-25/carlyle-group-sees-u-s-nuclear-industry-s-end-without-subsidies-iupx27u9?utm_content=bufferb7991&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer
[48] http://www.deccanchronicle.com/nation/current-affairs/230916/india-seeks-loan-from-us-for-6-nuclear-reactors-snags-remain.html
[49] IEEFA, Research Brief: A Half-Built, High-Priced Nuclear White Elephant, October 2017
[50] https://www.japantimes.co.jp/opinion/2016/12/23/editorials/cost-cleaning-fukushima/#.WgzzY7Z7G8U
[51] http://ieefa.org/wp-content/uploads/2017/10/IEEFA-Global-Utilities-in-Transition-11-Case-Studies-October-2017.pdf

6. Onshore Wind Power Generation

Under Prime Minister Modi's energy market vision, in 2015 India set a target to reach 60 GW of wind by 2022, up from 32 GW in March 2017. This implies national installs of 6 GW annually, a more than doubling of average installation rates over 2010-2017. In November 2017 Power Minister R.K. Singh announced plans to accelerate India's renewables investment program, with 20 GW of solar and 10 GW of wind to be added annually.[52] The record low renewable energy tariffs delivered over 2017 (down 50% since the start of 2016) set the economic framework to accelerate India's electricity sector transformation toward a more diverse, lower emissions system. With renewable costs continuing to fall, investing US$200-300bn in new generation capacity this coming decade could deliver sustained electricity system deflation.

December 2017 saw Gujarat award a 500 MW wind tender at a new record low of just Rs2.43/kWh (US$38/MWh),[53] 8% lower than the previous record low for wind set in May 2017, and 50% below the Rs4.50-5.00/kWh subsidised tariffs awarded pre-2017.

Extreme electricity sector deflation has caused near-term turmoil in India's wind sector, forcing a drive to introduce the latest technology and adopt the most-efficient corporate structures and procurement processes in order to restore sustainable profit margins. Industry leaders like Suzlon Energy are confident this adjustment process can be managed medium term, and install activity is likely to treble to 10 GW p.a. in line with the GoI's policy ambition.[54]

Overall, Tamil Nadu has 7.9 GW of installed wind capacity as of March 2017. The National Institute of Wind Energy (NIWE) estimates that TN's wind power potential is 34 GW at 100 metres, with significantly more available as 120-metre-tall turbines of Europe are introduced.

Wind: Tamil Nadu is a Global Leader

As of March 2017, Tamil Nadu has 7.85 GW of wind operational. This makes Tamil Nadu one of the largest states in the world in terms of operational wind farms. The province of Inner Mongolia in China is reported to have 25.57 GW at the start of 2017, with Xinjiang province second at 17.76 GW.[55] In America, Texas has 21.45 GW as of September 2017.[56] In Australia the smaller state of South Australia with a population of just 1.7 million has 1.78 GW of operational wind farms, representing almost 40% installed capacity, making it possibly the highest amount of installed capacity per capita in the world.

Sembcorp in April 2017 won a bid to build a 250 MW wind farm in TN, with PTC India taking the full offtake under a 25-year PPA. Commissioning is required by March 2019, and the full investment is Rs19bn.[57] Adding in potentially 900 MW from the August 2017 tender puts the state on track to reach at least 9 GW by the end 2018/19.

[52] https://economictimes.indiatimes.com/markets/stocks/news/solar-wind-stocks-soar-up-to-5-as-govt-plans-mega-tenders/articleshow/61817651.cms
[53] https://www.bloombergquint.com/business/2017/12/21/wind-power-is-now-the-cheapest-energy-in-india
[54] http://www.business-standard.com/article/companies/shift-to-bidding-regime-caused-short-term-pains-in-2017-suzlon-cmd-tanti-118010500271_1.html
[55] http://www.nea.gov.cn/2017-01/26/c_136014615.htm
[56] http://awea.files.cms-plus.com/FileDownloads/pdfs/Texas.pdf
[57] http://energy.economictimes.indiatimes.com/news/renewable/sembcorps-renewable-energy-arm-wins-250-mw-wind-power-project-in-india/58102904

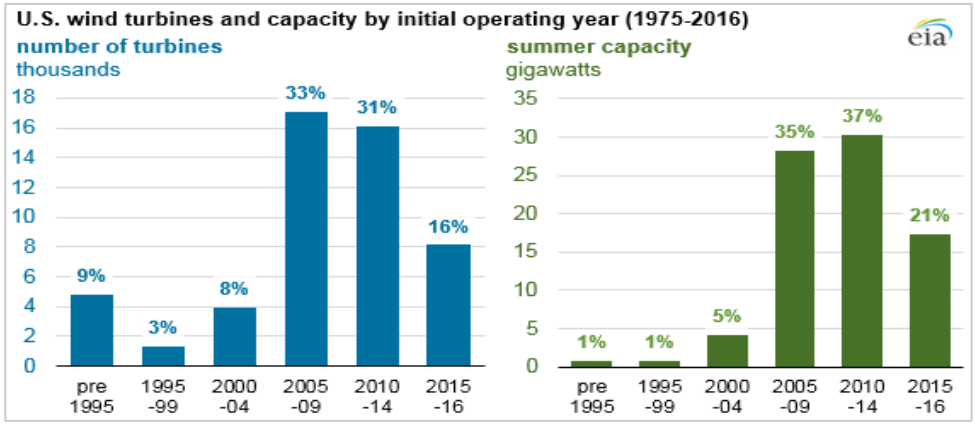
TN Wind: Record Low Tariffs

August 2017 saw the finalization of a 500 MW wind tender by TANGEDCO at a near TN state record low tariff of Rs3.42/kWh, 1% lower than the central government's then record low tariff award of Rs3.46/kWh in May 2017. ReGen Power Tech Company bid for 200 MW, Leap Energy 250 MW and NLC 500 MW of capacity, such that TANGEDCO is seeking TNERC permission to expand the auction from 500 MW to 900 MW to leverage these record low price offers.[58] IEEFA models a near doubling, to 15.0 GW, of operational wind by 2026/27 across Tamil Nadu.

Tamil Nadu's Repowering Opportunity

New Australian onshore wind farms being planned in 2017 have capacity utilisation rates of 45-50%, more than double that of the average Indian wind farm. With much of the Indian wind farm fleet approaching 20 years of age, the scope over the coming decade for repowering is significant. Replacing near end-of-life 200-500 kW turbines with higher towers and new models incorporating the latest 2-3 MW technology provides a scope for up to a tenfold increase in wind capacity and potentially twentyfold increase in generation (raising capacity utilisation rates from 15-20% to internationally comparable 30-35% rates) from existing projects whilst halving the number of towers required. A 2015 report by the Indo-German Energy Forum estimated that by 2025 TN would have 4 GW of wind capacity due for repowering, suggesting 40 GW of potential new capacity (36 GW net of closure and replacements).[59] The "Policy for Repowering of the Wind Power Projects" announced in August 2016 provides financial and taxation benefits for repowering of any wind turbine of 1 MW or below.[60]

Figure 6.1: Repowering Wind Turbines Adds Generating Capacity at Existing Sites



Source: U.S. Energy Information Administration, *Annual Electric Generator Report*, Early Release 2016 [61]

[58] http://energy.economictimes.indiatimes.com/news/renewable/wind-power-tariff-in-tamil-nadu-drops-to-3-42/unit-lowest-in-country/60268977

[59] http://idaminfra.com/wp-content/uploads/2015/12/AjitPandit_Presentation-on-Repowering-at-RExpo_23Sep2015_forwebcirculation.pdf

[60] https://economictimes.indiatimes.com/industry/energy/power/a-renewable-energy-investment-opportunity-not-to-be-missed/articleshow/62721968.cms

[61] https://www.eia.gov/todayinenergy/detail.php?id=33632

7. Offshore Wind – A Decade Away

Offshore wind costs are plummeting in Europe and this new technology is extremely promising, albeit roughly a decade behind the development curve of solar and onshore wind.

IEEFA expects offshore wind to emerge as a cost-competitive source of electricity generation system diversification for Tamil Nadu by 2025. Providing grid diversification is a key advantage of offshore wind, as are its absence of land requirements and its proximity to heavily populated coastal cities, particularly in Tamil Nadu given its prohibitive distance from India's thermal coal deposits.

Northern Europe accounts for 90% of global offshore wind developments to date, but with Taiwan,[62] South Korea,[63] China, Japan and the U.S. all investing now in the next phase of growth, further technology and scale advantages are expected to combine with significant "learning by doing" effects to drive cost deflation, [64] a trend that will be assisted by utilisation rates of more than 50%, double Indian onshore wind rates.

In the first half of 2017, China completed 2,066 MW of offshore wind projects, on track to meet its target of 10 GW of offshore wind under construction by 2020.[65]

IEEFA expects India's 3,100 km coastline will provide significant opportunity for further domestic electricity generation diversification as this technology becomes more cost competitive, and the long coastline of Tamil Nadu has some ideal sites.[66] While trial deployments are being studied, commercial scale remains some time off.[67]

While it is uncertain as to when Indian deployments might begin, costs continue to fall much faster than markets forecast. In September 2017, the U.K. government awarded three offshore wind projects totalling 3.2 GW through a contracts for difference (CfD) with strike prices going as low as £57.50/MWh for projects scheduled for commissioning in 2022/23.[68]

Following approval by the Union cabinet in October 2015, development planning for India's offshore wind industry has been coordinated by the FOWIND consortium, a collaboration and knowledge-sharing initiative with the EU, led by the Global Wind Energy Council.[69] An October 2017 report provided a grid integration study for offshore wind farm development in Tamil Nadu and Gujarat, with a target of connecting 500 MW in each by 2025.

In our Tamil Nadu state electricity model (refer Section 10), IEEFA assumes "just" 1 GW (US$3-4bn) of investment in offshore wind will be successfully commissioned by 2026/27, providing

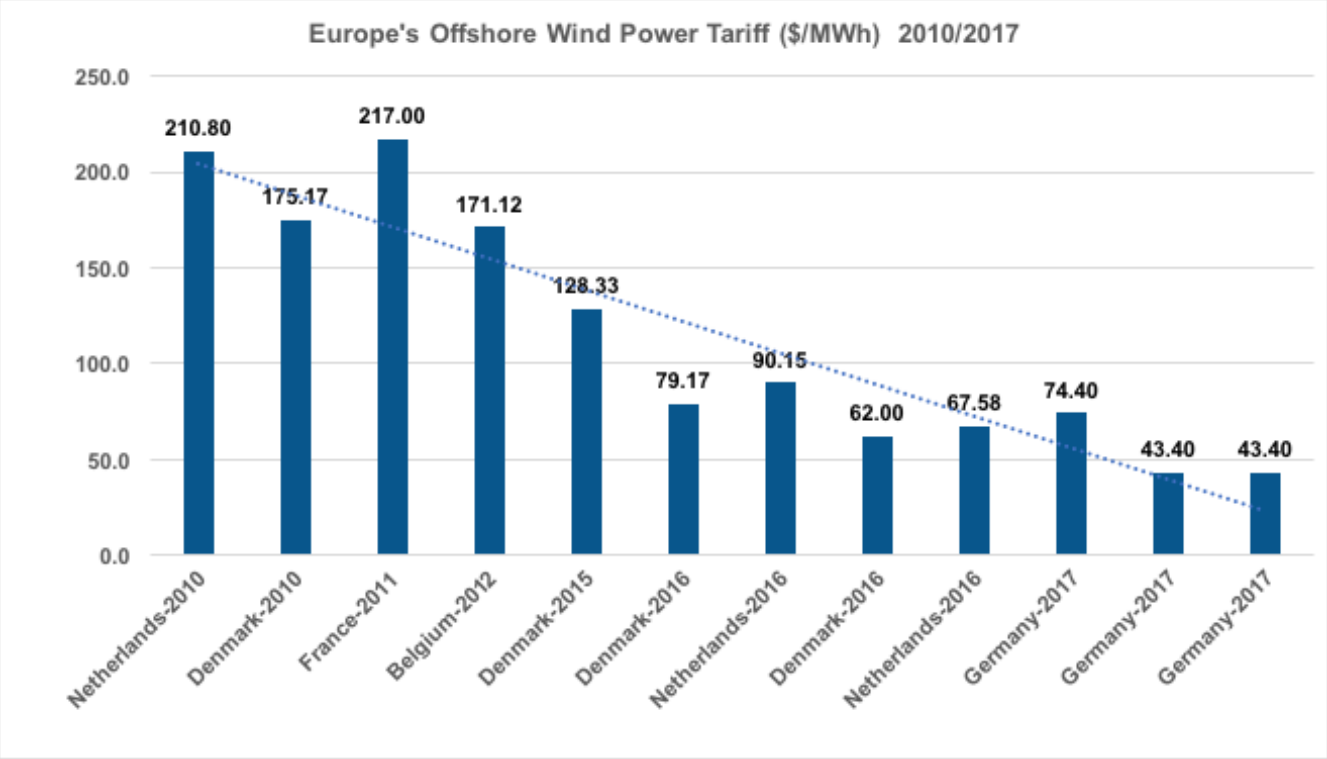
[62] https://www.bloomberg.com/news/articles/2017-06-18/taiwan-lays-plans-for-59-billion-in-renewable-energy-finance
[63] https://asia.nikkei.com/Politics-Economy/Policy-Politics/South-Korea-looks-to-turbocharge-renewable-power
[64] https://cleantechnica.com/2017/08/02/deepwater-wind-unveils-us-offshore-revolution-wind-farm-paired-tesla-energy-storage/
[65] http://www.hkexnews.hk/listedco/listconews/SEHK/2017/0825/LTN20170825878.pdf page 53
[66] http://energy.economictimes.indiatimes.com/news/renewable/offshore-wind-farms-can-be-potential-source-to-meet-energy-demand-scientists/60244562
[67] http://www.windpoweroffshore.com/article/1444224/two-offshore-sites-identified-india
[68] http://www.offshorewind.biz/2017/09/11/three-offshore-wind-projects-secure-contracts-for-difference-as-strike-prices-go-down/
[69] http://gwec.net/wp-content/uploads/vip/FOWIND_Report_on_Grid_Integration_for_Offshore_Wind_Farm_Development_in_Gujarat_and_Tamil_Nadu.pdf

learning by doing to facilitate a tenfold expansion in offshore wind across India in the following decade likely to cost half the price of the first 1 GW.

India Power Minister R.K. Singh surprised the market in December 2017 with the announced intention to tender for 5 GW of offshore wind as early as 2018.[70] This statement was in the context of accelerating deployments of renewable energy to raise India's zero-emissions generation capacity target of 175 GW by 2022 to in-excess of 200 GW.

While we applaud this clear and ambitious policy signal, IEEFA would caution against undue haste in the implementation timetable. Clearly Tamil Nadu and Gujarat have been identified as the two key coastal markets with the best offshore wind resources. The very low price of onshore wind and solar are an immediately cost competitive alternative. Secondly, a pre-requisite for offshore wind is the need to build a whole new supply chain and infrastructure system. Calling for a tender in 2018 with a 6-8 year progressive delivery timeframe (backed by cash deposits by winning proponents to ensure delivery) would provide the long-term security to achieve aggressive international bidding interest (particularly if a US$ financial hedge of the tariff can be facilitated). This should provide the necessary incentives to kick-start a major new industry in Tamil Nadu, one with excellent long-term growth opportunities.

Figure 7.1: European Offshore Wind Pricing Trends



Source: IEEFA
Note: Tariff for Germany-2017 auction is an estimation as the reported tariff is 'zero market premium' which means pricing is entirely merchant and on current forward prices, well below this.

[70] https://energy.economictimes.indiatimes.com/news/renewable/india-to-auction-5000-mw-offshore-wind-power-projects-in-2018/62068078

8. Solar Infrastructure

India has set an ambitious target of 100 GW of solar energy by 2022, and while installations to-date are behind schedule, IEEFA forecasts 2017/18 could almost reach 10 GW of new solar additions, marking the third consecutive year of near doubling in installs, showing momentum continues to build rapidly, underpinning the Indian electricity sector transformation.

November 2017 saw Power Minister R.K. Singh announce an ambitious target to accelerate solar installs to 20 GW annually through a reoccurring tendering program aiming for 30 GW in both 2018/19 and 2019/20. If achieved, this would provide the planning and procurement framework to build investor certainty, and expand manufacturing and EPC capacity to take advantage of record low, deflationary solar tariffs.[71]

As of June 2017 Tamil Nadu is no longer the top state in terms of installed solar capacity. Government data shows that Tamil Nadu, with an installed capacity of 1,697 MW, has fallen into third position behind Andhra Pradesh (2,010 MW) and Rajasthan (1,961 MW).[72]

Only 630 MW of solar power were installed in Tamil Nadu in 2016-17 against 919 MW in 2015-16. In the same period, Andhra Pradesh added 1,294 MW, Karnataka 882 MW and Telangana 759 MW. Across the country, 5,525 MW of solar energy were added in 2016-17, an increase of 66% over 2015-16.

A key constraint holding back the development of solar in TN has been TNERC's rejection of the tender process used in other states in recent years in favour of retaining the power purchase agreement (PPA) model. This has seen TN signing PPAs at well above rates evident in other states in the last 2-3 years. In 2015 TN signed PPAs at Rs7.01/kWh, 35-40% above the price struck on similar deals at similar times in Rajasthan and Madhya Pradesh.[73] Tariffs for solar projects in 2016 were struck at Rs5/kWh, but with TN's move to reverse auctions, July 2017 saw a record low (for TN) tariff of Rs3.47/kWh struck on 1.5 GW of new solar. This should see TN's total installed solar base double by end 2018/19.

Given the zero pollution and zero emissions nature of solar, plus the availability of large scale, immediately low cost tariffs with baked-in long term deflationary benefits, IEEFA forecasts that Tamil Nadu will see total solar installs increase sixfold by 2027 to 12 GW of utility scale plus 1.5 GW across the residential and C&I sectors. This is lower than reported targets for Tamil Nadu to set up 25 solar parks, each with a capacity of 500 MW and above, and reach more 20 GW of solar power installed capacity.

However, TANGEDCO needs to continue to resolve its financial distress (refer Section 9) and provide stronger regulatory credibility and discipline if it is to continue to benefit from the accelerating energy sector transformation that low cost renewables provide.

The latest two auctions treble solar projects under development across Tamil Nadu to 2.3 GW.

[71] https://www.pv-tech.org/news/indias-new-multi-gigawatt-solar-tender-plan-unrealistic
[72] http://energy.economictimes.indiatimes.com/news/renewable/tamil-nadu-falls-behind-andhra-pradesh-rajasthan-in-installed-solar-capacity/59817873
[73] http://energy.economictimes.indiatimes.com/news/renewable/tamil-nadu-fails-to-cash-in-on-solar-power-tariff-crash/59917702

New TN Solar Auction – 1.5 GW in July 2017

In July 2017 TANGEDCO announced the results of a second 1.5 GW solar tender at a new record low tariff for Tamil Nadu of Rs3.47/kWh after receiving bids totalling 3.7 GW. All bidders were required to accept the lowest bid outcome of the tender, but in contrast to the previous tender, the project completion deadline was doubled to 24 months. In August 2017 Tangedco was reported as ready to issue the 16 successful solar bidders letters of allocation such that the project developers can start land acquisition and arrange finance.[74]

Figure 8.1: Tamil Nadu Solar Tariffs Struck at Rs3.47/kWh in July 2017

TANGEDCO 1,500 MW Tender Results: Final List					
Company	Capacity (MW)	Price Quoted		Price Offered on 06 Jul 2017	
		₹/kWh	~$/kWh	₹/kWh	~$/kWh
Raasi Green Energy	100	3.47	0.0537	3.47	0.0537
Sai Jyoti Infrastructure Ventures	54	3.60	0.0557	3.47	0.0537
Solitaire BTN Solar (HPPPL)	100	3.69	0.0571	3.47	0.0537
Narbheram Vishram (Atha Group)	100	3.85	0.0596	3.47	0.0537
Rays Power Infra	100	3.85	0.0596	3.47	0.0537
NVR Energy (Atha Group)	100	3.85	0.0596	3.47	0.0537
Dynamize Solar	5	3.87	0.0599	3.47	0.0537
ReNew Solar	100	3.89	0.0602	3.47	0.0537
Sunlight (Udayasooriyan)	1	3.90	0.0603	3.47	0.0537
Talettutayi Solar Projects Two (Solar Arise)	50	3.90	0.0603	3.47	0.0537
Dev International	1	3.95	0.0611	3.47	0.0537
GR Thanga Maligai Firm (GRT)	10	3.96	0.0613	3.47	0.0537
GR Thangamaligai & Sons (GRT)	10	3.96	0.0613	3.47	0.0537
GRT Silverwares (GRT)	10	3.96	0.0613	3.47	0.0537
Shapoorji Pallonji Infra	50	3.96	0.0613	3.47	0.0537
NLC India	709	3.97	0.0614	3.47	0.0537
Total	1,500				

Source: TANGEDCO, MERCOM Capital[75]

The first February 2017 tender for a 500 MW solar auction received a tepid response due to stringent conditions such as a project completion deadline of 12 months. Bids were received for 292 MW from 20 entities. The biggest bidder was Rays Power Infra Pvt, which sought and won 100 MW at Rs 4.40 per unit. The project size eventually went down to 224 MW with 16 bidders. In June, TANGEDCO obtained regulatory approval for a uniform rate of Rs 4.40/kWh for 25 years. However, in August 2017 TANGEDCO announced it wanted to reduce the PPA pricing from the agreed Rs4.40 to just Rs3.47/kWh to match the excellent result of the 1.5 GW tender, refusing to sign the award documents and alternatively offering to cancel the agreements. This was reported to be in direct contradiction of the Tamil Nadu Electricity Regulatory Commission's (TNERC) order of 13 June 2017 directing it to sign all PPAs within the month.[76]

[74] http://energy.economictimes.indiatimes.com/news/renewable/wind-power-tariff-in-tamil-nadu-drops-to-3-42/unit-lowest-in-country/60268977
[75] http://mercomcapital.com/tangedco-to-sign-ppas-for-1500-mw-at-rs.3.47-$0.054kwh
[76] http://m.economictimes.com/industry/energy/power/tamil-nadu-latest-to-push-solar-companies-for-post-auction-tariff-cut/amp_articleshow/60077687.cms

Why Is Tamil Nadu Solar More Expensive?

Poor Discom Discipline has Lowered Investor Interest in Tamil Nadu

Regulatory risk in TN is clear. In August 2017 TANGEDCO notified the winners of the February 2017 tender auction that it would not sign the PPAs and was seeking a retrospective tariff reduction from the winning bid of Rs4.40/kWh to just Rs3.47/kWh, the rate tendered in the subsequent solar auction. In this instance, the distribution company is directly flouting the Tamil Nadu Electricity Regulatory Commission's order of June 2017 directing it to sign all PPAs related to the first auction and submit them within a month.[77]

The risks of payment delays by TANGEDCO also increases the cost of solar in Tamil Nadu.

Land Acquisition Risk and Lower Solar Radiation

Unlike Andhra Pradesh, which acquires land for solar parks, Tamil Nadu leaves developers the land acquisition responsibility, which takes time and increases capital risks for developers.[78]

The solar radiation in Tamil Nadu is lower than in the best locations of Rajasthan.

Grid Curtailment

The lack of contractual protection from curtailment risks by TANGEDCO also increases the cost of solar in Tamil Nadu, particularly for higher priced PPAs (be they solar or coal related).

In July 2017 TNERC rejected petitions from three Adani subsidiaries regarding implementation of must-run status of solar projects in TN. Adani Green Energy (Tamil Nadu) had petitioned against TANGEDCO, Tamil Nadu State Load Dispatch Centre (TNSLDC), Tamil Nadu Transmission Corporation Limited (TANTRANSCO) and the MNRE in relation to curtailment of power from Adani solar projects. TNERC rejected the petition as it found that the issue of "MUST RUN" status requires formal adjudication and not exercise of regulatory jurisdiction. TNERC has directed the petitioners to file the petition as a dispute resolution petition (DRP) to take the matter forward. The Appellate Tribunal for Electricity (APTEL) directed the TNERC chairperson to hear Adani Group's plea regarding the solar power curtailment issues.[79]

Rooftop Solar

Given the forecast doubling of electricity demand in India over the coming decade, plus significant land use constraints/conflicts and unsustainably high AT&C grid losses, distributed rooftop solar is a rapidly deployable, cost-effective solution that will play an increasingly material role in India's electricity sector transformation. India's national rooftop solar installation rate grew 81% year-on-year in 2016/17 to 678 MW, taking the total cumulative

[77] http://m.economictimes.com/industry/energy/power/tamil-nadu-latest-to-push-solar-companies-for-post-auction-tariff-cut/amp_articleshow/60077687.cms
[78] http://energy.economictimes.indiatimes.com/news/renewable/tamil-nadu-falls-behind-andhra-pradesh-rajasthan-in-installed-solar-capacity/59817873
[79] http://mercomcapital.com/tnerc-rejects-petition-from-the-adani-group

installed base to 1.4 GW.[80] The development of cost-effective net metering government policies and an easing of approval processes are both key to maintaining strong growth. The rapid development of ever-lower cost, behind-the-meter integrated lithium-ion battery storage systems will also accelerate rooftop solar deployments.

With a national rooftop solar target of 40 GW by 2022, installation rates need to double in both 2017/18 and again in subsequent years. The current installation rate and policy shortcomings suggest India is not on target for rooftop solar, with more conservative forecasts of 10-15 GW,[81] 60-75% short of the target. But putting this in the positive, it still would represent up to a tenfold increase on current capacity in just five years.

Heavy Discom subsidises of residential and agricultural tariffs (Rs2-4 and Rs0-2/kWh respectively) across India limit the cost-effectiveness of rooftop solar and solar irrigation pumps in these subsectors, absent the politically difficult task of tariff reform. However, the reverse also applies. The cross-subsidises of retail electricity prices make rooftop solar applications immediately cost effective in the C&I subsector (given tariffs of Rs6-8/kWh). With the excellent 1 GW Indian Railways solar target providing an immediate uplift in activity to encourage capacity and skills building, IEEFA expects rapid growth to be maintained.

Tamil Nadu is the leading state in India with respect to rooftop solar. As of March 2017, installs totalled 163 MW, 12% of India's total. If Tamil Nadu can maintain its sector leadership, this would imply 1-2 GW of rooftop solar is a conservative target by 2026/27, requiring 100-200 MW annually over the coming decade. While a significant step-up on current deployments, it is worth putting this forecast in an international context. Australia's population is one-third of TN's 72 million, but Australian rooftop solar installations have run at an average of 1 GW annually over the last six years. One third of the population and ten times the installation rate. China installed some 36 GW of mostly C&I rooftop solar in 2017 alone. India's ambitious plan of 40 GW of rooftop solar currently has issues of quality deficits in terms of operations and maintenance of the program as admitted by MNRE secretary Anand Kumar. He has recently mentioned that a new scheme is in development—SRISTI (Sustainable Rooftop Implementation for Solar Transfiguration of India), which will aim to address the clashes between the interests of Discoms and high-end consumers[82].

As mentioned above, consumer tariff subsidies are a major impediment to rooftop solar growth. A second impediment appears to be TANGEDCO, which in July 2017 proposed to buy surplus rooftop solar generation at just 50% of the retail tariff, while also proposing new solar capacity limits.[83] The company clearly needs to give consideration of social equality and grid investment cost recovery. However, with the need to also encourage rapid investment in new generation capacity to match forecasted electricity demand growth, this policy proposal will prove counter-productive; stalling residential rooftop installations (a heavily subsidised sector) and encouraging rooftop solar + storage in the most profitable C&I sector. TANGEDCO should learn from international experiences; Discoms can play a key role in facilitating cost-effective electricity sector transformation, but they can't stop an inevitable technology change. New technology applied systematically and in the most logical sizes and locations can best manage and enhance system development and stability.

[80] http://www.thehindubusinessline.com/economy/tamil-nadu-maintains-lead-in-solar-rooftop-installations/article9767427.ece
[81] https://mercomindia.com/power-tariffs-policy-rooftop-market/
[82] https://energy.economictimes.indiatimes.com/news/renewable/sluggish-rooftop-solar-scheme-spurs-government-to-work-on-new-plan/62569111
[83] https://timesofindia.indiatimes.com/city/chennai/tn-to-tax-rooftop-solar-cut-support/articleshow/59480653.cms

9. Discom Reform

Critical to any sustained momentum in the Indian electricity sector transformation is permanent reform of the state distribution sector's appalling financial distress, with annual unfunded losses nationwide reported as high as US$10bn in 2013/14.

In 2016, Piyush Goyal, then the minister for power, coal, and new and renewable energy, launched the Ujwal Discom Assurance Yojana (UDAY) scheme to turn around highly indebted state power Discoms, starting with debt reform (acknowledging total indebtedness but also lowering the interest rate by bringing it onto state governments' balance sheets) plus a focus on reducing AT&C losses (including theft), reducing power outages, reducing corruption and inefficiencies, enforcing policy implementation, and progressively narrowing the deficit between average revenue received and average cost of supply.[84]

In January 2018 Power Minister R.K. Singh reported to the Lok Sabha that across the 24 states implementing UDAY, collective losses have been reduced by 30% from Rs51,590 crore in 2015/16 to Rs36,905 crore (US$5.7bn) in 2016/17.[85] A key aspect of the improvement was a full 1% reduction in AT&C losses.

TANGEDCO Finally Adopts UDAY, to Immediate Positive Effect

TANGEDCO reported a record unfunded loss of Rs13,985 crore (US$2.1bn) in 2013/14, and the ongoing financial distress has been a major constraint on electricity sector progress in TN. Repeated failure to pay for power purchases and the lack of bankability of Discom-backed PPAs due to the dire state of its balance sheet has pushed up the cost of electricity supply by 30-40% relative to other, stronger states.

June 2017 saw the announcement that TANGEDCO was targeting a breakeven profit result for 2017/18,[86] building on a dramatic recent improvement following 15 years of deficits. TN Electricity Minister P Thangamani reported that the company's 2016/17 loss had been reduced by three quarters in just three years to Rs3,783 crore (US$582m) through bringing debt on balance sheet and accessing lower interest costs, higher tariffs, reduced ACS, including accessing cheaper interstate electricity supply, plus better coal supply arrangements including reduced reliance on imported coal.

The UDAY dashboard reports the current statistics for TN in 2017/18: [87]

- AT&C losses running at 13.84% in September 2017, fractionally behind their 2017/18 target of 13.79% but down from the 14.53% reported for 2016/17;
- A ACS-ARR gap of Rs0.22/kWh, well above the Rs0.06/kWh target but a one-third reduction on the Rs0.36/kWh loss incurred with every unit of electricity sold in 2016/17;
- A net loss for 1H2017/18 of Rs11bn (US$170m) vs the target of a breakeven result, but still a run-rate half of that reported in 2016/17; and
- Debt issuance of Rs228bn, 75% of the fiscal year target of Rs304bn (refinancing is critical).

[84] http://www.livemint.com/Politics/7pKwAJCjhMZjqqLZxidSDN/UDAY-is-a-game-changer-Piyush-Goyal.html
[85] https://economictimes.indiatimes.com/industry/energy/power/24-states-under-uday-cut-losses-to-nearly-rs-37000-cr-in-fy17/articleshow/62366800.cms
[86] http://www.business-standard.com/article/pti-stories/tangedco-to-break-even-in-2017-18-117061900809_1.html
[87] https://www.uday.gov.in/state.php?id=21&code=Tamil%20Nadu

Similarly, TANGEDCO has progressively reduced the deficit on energy requirement and availability from 12.3% in 2011/12 to a record low of 0.6% in 2015/16, a signature improvement.

TN also has made excellent progress on its planned rollout of electricity saving LEDs (installing 560,000 LEDs, double the target), but TANGEDCO has yet to make progress on smart metering, given political disputes over the tender process and cost of proposed meters.[88]

Accurate and Timely Data Disclosure Is a Key Strength of UDAY

One of the key strengths of the UDAY scheme is the push to increase timeliness of disclosure and transparency of detailed data at the individual Discom level. Nothing works better than competition rivalry, plus public disclosure and government encouragement for the Discoms to improve their relative and absolute rankings.

The "Power for All Tamil Nadu" 2017 report[89] is a serious credit to the Government of Tamil Nadu and TANGEDCO, disclosing the issues, providing hard analysis of the problems and setting out clear targets and solutions. TANGEDCO wouldn't have allowed such a report two years ago, it would have been too embarrassing. To IEEFA, its existence is proof that a solution is well under way: a net profit for TANGEDCO is in sight—to the sustained benefit of all of TN.

TANGEDCO Drives Down the Average Cost of Supply (ACS)

A key area for further savings over time will be through lowering the average cost of procurement. New renewable energy procurement in TN is running at Rs3-4/kWh. Applying an economically logical merit order for electricity source selection means that TANGEDCO would first take lower cost wind, solar, hydro and even nuclear (at Rs4/kWh) ahead of any non-pithead coal-fired power plants that have contracted a much higher cost for supply, reported at Rs4.91-5.23/kWh. Since mid-2017, TANGEDCO has been extracting significant tariff reductions from coal-fired power producers, procuring electricity at a reported Rs4.10/kWh.[90] At this new norm, most if not all proposed new non-pithead coal-fired power plants will be uncompetitive and will struggle to achieve financing absent government subsidies.

The same downward tariff pressure applies to any high cost PPAs that don't have legally binding volume off-take agreements. Only 30% of Adani's 648 MW solar project was completed consistent with the contracted timeline (completion by March 2016). Given this solar plant originally attained a controversially high Rs7.01/kWh PPA, the 70% of the plant commissioned after the due date has been receiving a lower Rs5.10/kWh tariff. Even at this lower rate, the plant is not competitive with new renewables of Rs3-4/kWh or new pithead lignite power plants at Rs3-4/kWh. TANGEDCO is likely to curtail use of this expensive resource.

In July 2017 reports detailing the ACS from various generators detailed opportunities for TANGEDCO to save US$300m annually by implementing the merit order and negotiating tariff reductions to expensive PPAs.[91] This will materially reduce TANGEDCO's operating loss.

[88] https://timesofindia.indiatimes.com/city/chennai/opposition-parties-flay-tn-govt-for-purchasing-power-meters-at-higher-cost/articleshow/61672116.cms?utm_source=twitter.com&utm_medium=social&utm_campaign=TOIChennaiNews
[89] http://www.powerforall.co.in/AccessFolder/PFA_Document/1_PFA_Tamilnadu09012017.pdf
[90] http://energy.economictimes.indiatimes.com/news/power/tamil-nadu-power-utility-to-save-rs-2000-crore-per-year-in-discounts/59649951
[91] http://energy.economictimes.indiatimes.com/news/power/tamil-nadu-power-utility-to-save-rs-2000-crore-per-year-in-discounts/59649951

Driving Up Average Revenue Received (ARR) Is Closing the Gap

TANGEDCO saw a staggering Rs2/kWh shortfall in ARR relative to ACS each year over 2010/11 through to 2013/14. This created an entirely unsustainable dilemma for the company, its unfunded losses increased the more it did its job; the more electricity it sold, the greater its losses. This per unit shortfall dropped 20% in 2014/15, and another 30% to Rs1.09/kWh in 2015/16. With the benefit of lower-priced renewables driving down average ACS, the current trajectory means to IEEFA that TANGEDCO should reach a much needed ARR > ACS by 2018/19, particularly if average tariff increases can be delivered to cover underlying 3-4% per annum inflation. Low cost renewables and interstate grid connectivity is playing a key role in reform.

TANGEDCO Debt Reform, Long Overdue

A key component driving the success of UDAY is the need for the Discoms to bring onto the states' balance sheets the full extent of previously 'hidden' or off-balance-sheet debts. TANGEDCO has been in dire financial distress. Long-term debt ballooned 300% from Rs194bn in 2010/11 to Rs672bn (US$10.5bn) in 2014/15. This clearly reflects the impossible trilemma of growing capacity of generation and the grid to accommodate sustained growth, plus selling electricity for Rs2/kWh less than it costs to buy, and losing 20-25% of all electricity procured through theft and grid T&D losses. One reform step now implemented is to lower the cost of debt servicing by bringing it on-balance sheet for the state. This has immediately lowered interest rates by 2%, saving US$200m annually. Stemming unfunded losses is another key step, and excellent progress here is finally under way.

TANGEDCO Is Finally Showing Serious, Much-Needed Reform

In a shot in the arm for TANGEDCO, the Fifth Annual Integrated Rating, 2017, of State Distribution Utilities has upped the company's performance from 'C' (low performance) last year to 'B' (below average). The report, however, does flag that serious concerns remain about the company's health, including the growing subsidy support from the Tamil Nadu government. M. Saikumar, chairman of TANGEDCO, said he was happy the company has made an improvement from 'C' last year to 'B' this year and was hopeful of achieving an 'A' grade next year. The rating done by the ICRA and Credit Analysis and Research under the auspices of the Ministry of Power has positioned TANGEDCO in the 25th place all-India, up from 34th last year. The rating was carried out among 41 electricity distribution companies covering 22 States.[92]

The report also mentions the high dependence on TN state government subsidies, which now stands at Rs6,879 crore (US$1.1bn) for 2015-16, as against Rs952 crore (US$150m) in 2004-05. In 2014-15 the subsidy was Rs 5,599 crore (US$0.88bn). Tariff reform should assist over time, but ultimately a halving of the unsustainably high AT&C losses is needed (Figure 9.1).

[92] http://www.thehindu.com/news/national/tamil-nadu/tangedco-gets-a-boost-in-performance-rating/article18402249.ece

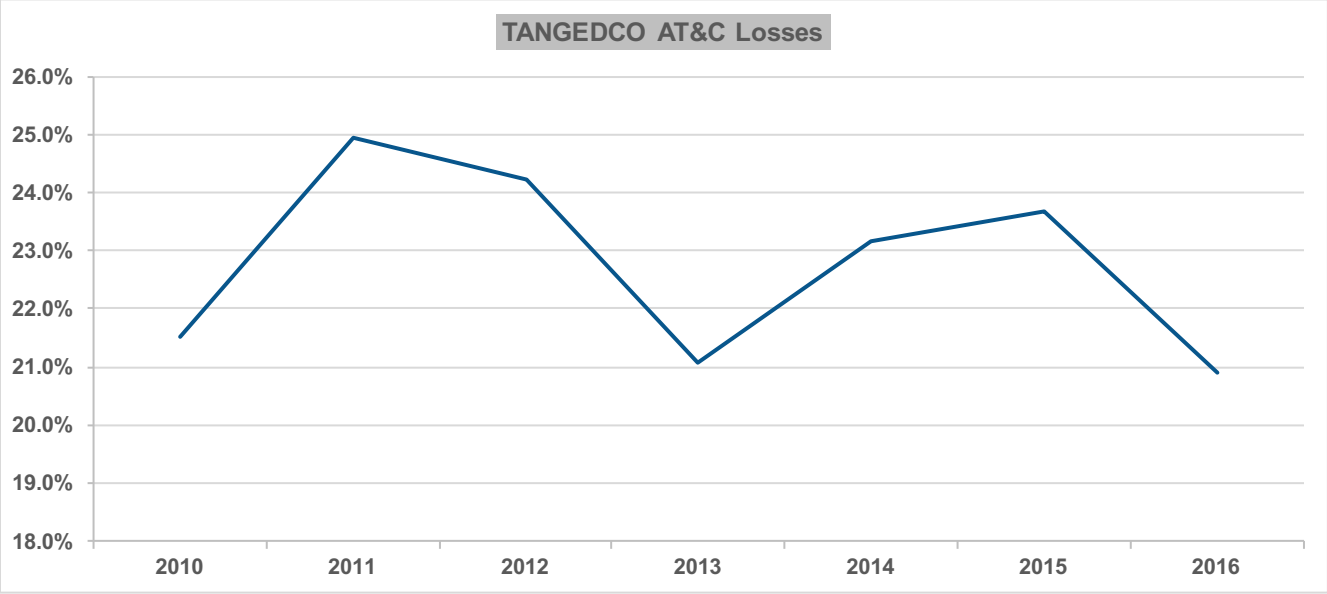
Improving Building Energy Efficiency Provides a Major Opportunity

IEEFA would note the very material opportunity to limit overall electricity demand growth and hence pollution and investment pressures by the introduction and enforcement of building-efficient policies. India took an important step forward in June by launching the revised Energy Conservation Building Code (ECBC) 2017.[93] TANGEDCO should be encouraged to accelerate the implementation of this program across TN, notwithstanding the potential conflict of interest it has in terms of the implications of subduing demand growth from high tariff industry & commercial customers. The company also needs to work in the long-term interests of the state to accelerate energy system reform regardless of perverse incentives that result from cross-subsidies from C&I to facilitate free electricity to the agricultural sector.

AT&C Losses: Unsustainably High

IEEFA notes there is a major discrepancy between the TN UDAY dashboard (2016/17 at 14.5%)and the TN Ministry of Power Report of 2016 (variously reported at 20.9% or 20.13% in 2015/16[94]). Figure 9.1 details the historic figures as reported by the TN Ministry of Power, and IEEFA's TN Electricity model (Section 10) works from this higher starting point in our analysis.

Figure 9.1: Tamil Nadu AT&C Loss Rates - 2009/10-2015/16



Source: Ministry of Power, Tamil Nadu, Power for All Report page 29

[93] http://www.wri.org/blog/2017/11/indias-move-make-buildings-efficient
[94] http://www.thehindu.com/news/national/tamil-nadu/tangedco-gets-a-boost-in-performance-rating/article18402249.ece

Interstate Grid Connectivity

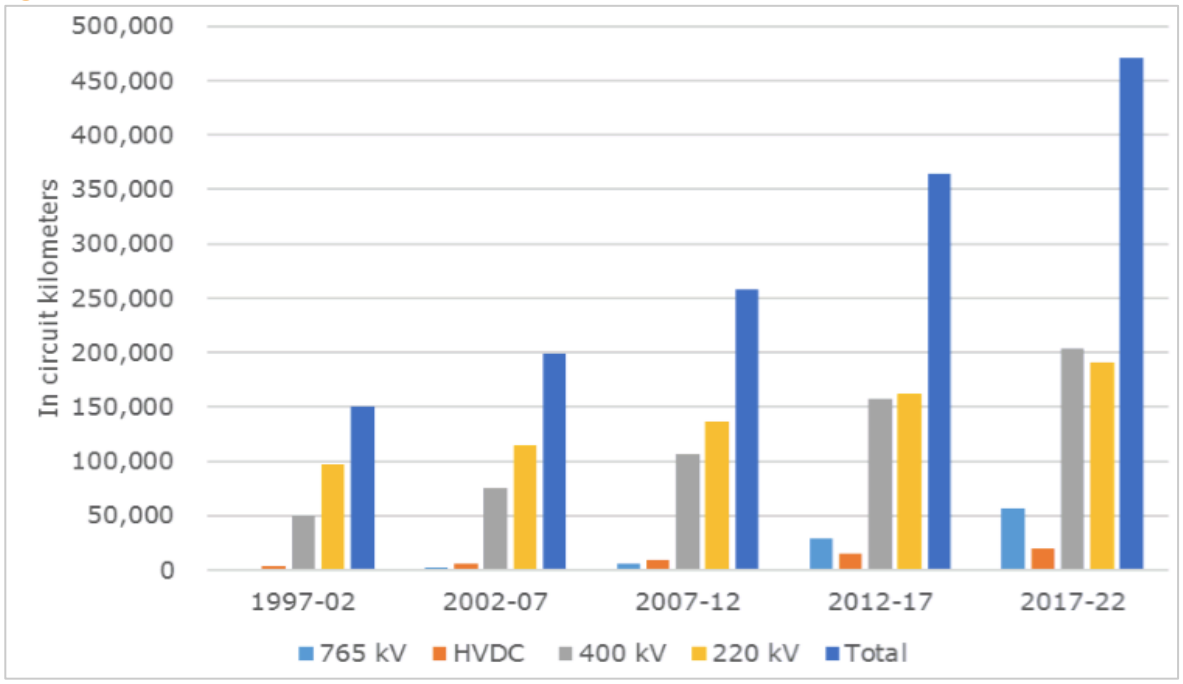
One of the strengths of the Indian electricity system is the national connectivity. This brings significant geographic spread and connectivity across both 1.32 billion people in India, and some initial connectivity into neighbouring Bangladesh, Bhutan and Nepal, plus the potential to integrate with Sri Lanka in due course.

India has invested some US$20bn annually in upgrading and expanding grid transmission and distribution (T&D), with the development of greater national grid connectivity a key focus of the last decade. This has seen the integration across five previously discrete regional grid systems, with a three-fold expansion between 2002 and 2022 (Figure 9.2).

As part of this, India has undertaken a Rs430bn (US$7bn) "Green Energy Corridor Project" to expand transmission capacity across renewable energy-rich states including Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Madhya Pradesh and Himachal Pradesh. This is due for commissioning in March 2019.

Selling excess renewable energy power to neighbouring states is a logical opportunity to leverage TN's investment. In November 2017 it was reported that TN achieved a major first—electricity exports of 12 GWh worth US$1m in just 14 days (Rs5.16/kWh) during the monsoon.[95] While US$1m is immaterial to the overall US$2-3bn of electricity sector investment going into Tamil Nadu annually, it is a clear signal regarding the range of opportunities that are emerging (not the least being reduced air and water pollution pressures).

Figure 9.2: Growth in Transmission Capacity Across India



Source: Fowind "Grid Integration Report, October 2017

[95] https://cleantechnica.com/2017/11/21/indian-state-earns-nearly-1-million-selling-excess-wind-power-14-days/

10. IEEFA Electricity Model for TN

Tamil Nadu already operates one of the most well-diversified electricity generation fleets in India, with renewables representing 35% of installed capacity as of March 2017, nuclear 8% and hydroelectricity 7% of the total (Figure 3.1). Coal-fired power generation amounts to 45% or 13.4 GW of the total (and an estimated 69% of 2016/17 generation); this represents a combination of low cost pithead lignite production (owned and operated by NLCIL) plus non-pithead thermal coal-fired power. Tamil Nadu's coal generation is sourced from expensive non-pithead power plants that must procure coal from the northeast coalfields of India, transported up to 1,650 km (refer Section 4).

Herein lies both a significant opportunity and threat for Tamil Nadu. Within TN there is a coal-fired power plant pipeline of 22.5 GW at various stages of announcement, pre-permitting, fully permitted and even a number under construction (plus 1.1 GW of proposed but not built gas-fired power capacity stalled as well). Absent replacement of end-of-life thermal capacity, Tamil Nadu does not need any net new thermal power capacity additions this coming decade. Building net new thermal capacity would just further depress existing low utilisation rates and create further financial distress for the thermal power sector.

IEEFA's electricity demand and supply model for Tamil Nadu over the coming decade to 2026/27 suggests that a doubling of economic activity will drive a 72% uplift in electricity demand (assuming a ~1% annual energy efficiency savings). But if AT&C losses can be reduced 0.75% annually from 20% in 2016/17 to just under 13% by 2026/27, electricity production requirements will rise by just 57% or 60 TWh annually.

The addition of 10.3 GW of new utility-scale solar by 2026/27 looks entirely commercially feasible after the 1.5 GW solar auction of July 2017 at just Rs3.47/kWh. Combined with 1.5 GW of rooftop capacity, solar is forecast to provide one-third of all new generation needs this decade. Onshore and offshore wind capacity additions will provide an estimated 41% of the production uplift needed. Bringing online the 1 GW Unit 3 of Kudankulam nuclear would provide 19% of new supply needs, with biomass and run-of-river hydro the balance. Total installed capacity expands to a forecast 55 GW by 2026/27 and coal-fired generation is reduced from 69% to just 42% market share in Tamil Nadu (Figure 10.1).

Figure 10.1: Tamil Nadu's Electricity Production & Consumption 2026/27

Source	Electricity market Composition 2026/27				
	Capacity		Generation		Capacity
	GW	% of Total	TWh	% of Total	Utilisation
Coal	16.6	30%	65.9	42%	45%
Gas	1.0	2%	2.2	1%	25%
Diesel	0.4	1%	0.9	1%	25%
Hydro	2.3	4%	5.3	3%	26%
Nuclear	3.4	6%	21.1	13%	70%
Renewable	31.2	57%	62.8	40%	23%
Total	**55.0**	**100%**	**158.3**	**100%**	

Source: IEEFA calculations and forecasts

Decoupling Electricity vs Economic Growth

The October 2017 grid integration report by FOWIND forecasts an 11% compound annual growth rate in electricity demand in TN over the coming five years. While singling this one report out, IEEFA notes such a forecast reflects an ongoing trend of over-estimating electricity demand growth, both within India and globally. In November 2017 the U.S. Energy Information Administration (EIA) published an analysis noting the increasing evidence of a systemic decoupling of electricity demand from economic growth.[96] IEEFA's analysis shows this same decoupling trend is evident in Europe, America, Japan and Australia.

Most importantly for the global picture—there was a major decoupling of electricity demand from economic growth in China post 2013. For the period 2000-2013, electricity demand grew in lockstep with economic growth of 10% annually in China; a ratio of 0.9 times. Since 2014, the ratio almost halved to 0.5 times.

IEEFA projects a more modest 5.6% CAGR in electricity demand over the coming decade to 2026/27. We reference the historic TN electricity demand growth of 6.7% annually relative to real GDP growth of 7.7%, giving a ratio of 0.86. IEEFA assumes a gross ratio of 0.94 over the coming decade. This reduces to a net ratio of 0.80 (electricity demand to economic growth) if a 1% annual energy efficiency saving can be sustained over the coming decade. Moves to introduce LEDs, high-rated air conditioners, solar irrigation pumps and better building construction standards will all assist materially in this least cost, least polluting source of procurement—the electricity production not needed.

Another key option for reducing the need for new generation is reducing AT&C losses across Tamil Nadu from 20% currently to less than 13% by 2026/27, or 0.75% annually. This is an absolutely core principle of the UDAY program. This is key to ensuring electricity production growth grows at a rate below electricity demand through reduced waste of electricity during transmission and distribution. Reduced power theft most likely requires the roll-out of an automated smart meter system that would immediately cease any bribery of meter reader staff, not to mention the efficiency gains relating to any associated investment in distributed, behind the meter rooftop solar and/or storage systems – refer Section 8.

IEEFA's TN model assumes a 60 TWh or 57% increase in electricity production to 164 TWh annually by 2026/27. Deducting 12.7% AT&C losses in 2026/27 gives net demand in TN of 143 TWh, a rise of 60 TWh or 72% over the decade. This is predicated on 7.0% real GDP growth annually, in line with IEEFA's forecast for India overall. The ratio of electricity demand growth to economic growth is forecast at 0.80, net of a forecast 1.0% annual energy efficiency dividend (Figure 10.2).

TANGEDCO's improving financial profile is forecast to move into a net profit for the first time in two decades within 2-3 years as the average cost of supply (ACS) continues to fall to Rs3-4/kWh and average revenue received (ARR) moves up toward Rs5/kWh in line with annual Indian inflation of 4-5%. An economic transition toward industry and services plus an accelerated rollout of distributed solar should progressively reduce the state's funding burden and ARR penalty relating to heavily subsidised or free agricultural sector electricity. A profitable Discom should allow stronger reinvestment in T&D upgrades and lower PPA risks.

[96] https://www.eia.gov/todayinenergy/detail.php?id=33812

Figure 10.2: Tamil Nadu's Electricity Production & Consumption 2017/18 - 2026/27

Year ended March	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Gross Production (TWh)	80.0	92.7	96.5	104.4	109.2	114.2	119.5	125.0	130.8	136.8	143.2	149.9	156.9	164.2
Gross Production Growth (%)		15.9%	4.1%	8.2%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.7%	4.7%	4.7%
AT&C Losses (TWh)	18.5	21.9	20.2	21.0	21.2	21.3	21.4	21.4	21.5	21.4	21.4	21.2	21.0	20.8
AT&C Losses (%)	23.2%	23.7%	20.9%	20.2%	19.4%	18.7%	17.9%	17.2%	16.4%	15.7%	14.9%	14.2%	13.4%	12.7%
Reduced Grid losses		0.5%	-2.8%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%	-0.75%
Real GDP Growth (%)	7.3%	7.2%	8.8%	7.9%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
Electricity Multiplier (x)	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Electricity Growth (%)	6.9%	6.8%	8.3%	7.5%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%
Energy Efficiency	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
Net Demand Growth (TWh)	61.4	70.7	76.3	83.3	88.0	92.9	98.1	103.5	109.3	115.4	121.9	128.7	135.8	143.4
Net Demand Growth (%)		15.1%	7.9%	9.2%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%

Source: CEA, IEEFA calculations and forecasts
Note: The IEEFA model does not try to account for electricity imported/exported by the state due to unavailability of data. We note this shortcoming is material for nuclear generation as an example, given more than 50% of generation is contracted to other states.

New Demand Met by Zero Emissions Supply

IEEFA's forecast for the addition of 10.3 GW of new utility-scale solar means TN would reach 12.0 GW in total by 2026/27. Combined with 1.5 GW of rooftop solar + behind-the-meter storage capacity, IEEFA forecasts for solar to provide one-third of all new generation needs this decade. We assume one 300 MW concentrating solar thermal power with storage is built by 2026/27, providing relatively higher cost (Rs5/kWh) peaking supply for early evenings.

Capacity additions of onshore wind including the progressive repowering of end-of-life projects should add a net 7.1 GW of new wind to reach 15 GW (25% average capacity factor (CF), up from just 17.5% in 2016/17)) and with the likely commissioning of India's first offshore wind farm (1.0 GW operational by 2026/27 with a 40% CF) will provide an estimated increase combined of 25 TWh annually—or 41% of Tamil Nadu's total production uplift needed.

Bringing online the 1 GW Unit 3 of Kudankulam and solving production issues with Units 1 & 2 to allow a forecast 70% average capacity factor on 3.4 GW of nuclear would provide an uplift of 11 TWh or 19% of TN's new supply needs.

Adding 0.5 GW of biomass/waste-to-energy and 0.11 GW of new run-of-river hydro (taking total hydro to 2.3 GW running at a CF of 26% vs just 12% in the drought affected 2016/17 year) would provide the balance and improve grid diversity of generation.

Total installed capacity in Tamil Nadu is forecast to expand to 55 GW by 2026/27. We assume no change in the current 1.0 GW of existing gas-fired power capacity.

With non-pithead coal-fired generation increasingly the high cost source of supply (both in terms of the fully loaded cost of new capacity but also in terms of short run marginal cost of supply, given wind, solar and hydro each have a near zero marginal cost of supply, and nuclear once built is similar), imported thermal coal is forecast to supply the balance of TN electricity production needs, which is -1 TWh (Figure 10.3).

Figure 10.3: Tamil Nadu's Net Electricity Consumption 2017/18 - 2026/27

Tamil Nadu's Waterfall Chart				
Net Electricity consumed in Tamil Nadu in 2016/17 (TWh)			83	
Real GDP Growth	7.0%	pa		
Electricity to GDP multiplier	0.94	times		
Electricity Demand Growth	6.6%	pa	62	
Energy Efficiency	-1.00%	pa	-2	
Growth: gross production losses			12	
Reduced grid AT&C losses	-0.75%	pa grid efficiency gain	-12	
Net Electricity consumed in Tamil Nadu in 2026/27 (TWh)			143	
Net expansion in Electricity demand 2026/27 (TWh)			60	
Net expansion in electricity production required (TWh)			60	
The Increase in Net Electricity Demand is met by (TWh)			**TWh**	**Uplift**
Solar expansion			17	29%
Solar rooftop expansion			2	4%
Solar thermal expansion			1	2%
Onshore wind expansion			21	35%
Offshore wind expansion			4	6%
Increase in biomass generation			1	2%
Increase in hydro electricity			3	5%
Increase in gas-fired electricity			0	0%
Increase in nuclear generation			11	19%
Change in Coal-fired power use			-1	-1%
Net expansion in Electricity Production by 2026/27 (TWh)			60	100%

Source: CEA, IEEFA calculations and forecasts

Coal-Fired Power: Collapsing Utilisation

Under IEEFA's TN model, with the assumption that TN completes all plants under construction (4.5 GW) and half of those new coal-fired power plants already permitted (50% of 5.0 GW), high priced coal-fired power plant capacity utilisation will collapse. So even allowing for the closure of all the 3.75 GW of beyond end-of-life coal-fired power plants (units exceeding 35 years of age by 2026/27), total coal capacity will reach 16.6 GW by 2026/27, and utilisation rates will collapse to an entirely unsustainable 45% average by 2026/27 (with expensive to run imported coal-fired power utilisation falling faster, given pithead lignite is much lower cost). With TN non-pithead coal-fired power generation costs very high by Indian standards, there is little capacity for TN to export non-lignite based thermal power to other states.

Conclusion

The early 2017 review on Tamil Nadu's stalled 4.0 GW imported coal-fired Cheyyur UMPP by Keith Schneider titled: "Chased by Drought, Rising Costs, and Clean Technology, India Pivots on Coal"[97] provides a telling review of the energy sector transformation under way in Tamil Nadu. It was highlighted that this is being driven by twin pressures: first, the rising financial constraints relating to the growing recognition of stranded asset risks for thermal power projects by proponents and, more importantly, the Reserve Bank of India (particularly for expensive imported coal plants); and second, the increased community alarm and resistance against ever-rising air and water pollution plus encroachment on private landowners from compulsory land acquisition.

As 2018 commences, these forces have accelerated beyond almost anyone's expectations either within India or internationally, maybe apart from former Energy Minister Piyush Goyal.

The end of 2017 saw yet another record low wind tender outcome of just Rs2.43/kWh, down 8% on the previous record low and down 50% on pre-2016 wind tariff norms. This result also means that wind has now replicated the amazing deflationary trends witnessed across India in solar in the last two years. With competitively priced wind and solar both available in Tamil Nadu, this provides a much-needed accelerant to the already leading profile of the state in terms of installed renewable energy capacity.

With 10.6 GW of renewables plus 2.2 GW of hydro operational as of March 2017, this represents a 42% share of total installed TN power generation capacity (an 18% share of generation). Tamil Nadu is the leading state in India in terms of installed wind capacity, making it also one of the top states globally behind only a few provinces in China and Texas in America. Tamil Nadu has temporarily slipped to third position in terms of commissioned solar infrastructure in India, but the very successful 1.5 GW solar tender of July 2017 will see TN vie for leadership again by the end of 2018/19. Mid-2016 saw Adani Green's 648 MW Tamil Nadu facility briefly hold the world record in terms of the largest single-site solar project.

Tamil Nadu's bankrupt Discom TANGEDCO reported a record unfunded loss of US$2.2bn in 2013/14. The idea that TANGEDCO could possibly actually turn a profit by 2018/19 would have seemed ludicrous just 1-2 years ago, yet with the progressive implementation of the UDAY reform program this now looks entirely achievable.

Tamil Nadu provides an excellent case study of the potential to transform an electricity system, progressively increase reliance on renewables even whilst at the same time lowering average cost of electricity supply and sustaining a strongly growing economy.

With 72 million people, Tamil Nadu is a state that is bigger in population than most countries around the world. The ability to rapidly shift to a progressively greater reliance on lower cost, zero emissions generation sources is illustrative for many emerging markets internationally. By 2026/27 IEEFA forecasts 67% of installed capacity and 56% of generation in TN will be derived from zero emissions technologies.

[97] https://www.newsecuritybeat.org/2017/04/chased-drought-rising-costs-clean-technology-india-pivots-coal-power/?utm_content=buffer382ac&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

Institute for Energy Economics and Financial Analysis

The Institute for Energy Economics and Financial Analysis (IEEFA) conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy and to reduce dependence on coal and other non-renewable energy resources. More can be found at www.ieefa.org.

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Tim Buckley, IEEFA's director of energy finance research, Australasia, has 25 years of financial market experience covering the Australian, Asian and global equity markets from both a buy and sell side perspective. Tim was a top-rated Equity Research Analyst and has covered most sectors of the Australian economy. Tim was a Managing Director, Head of Equity Research at Citigroup for many years, as well as co-Managing Director of Arkx Investment Management P/L, a global listed clean energy investment company that was jointly owned by management and Westpac Banking Group.

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Important Information