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Lessons From Australia for India on Integrating Distributed Energy Resources (DER)

Technical Integration Is the First Priority

Executive Summary

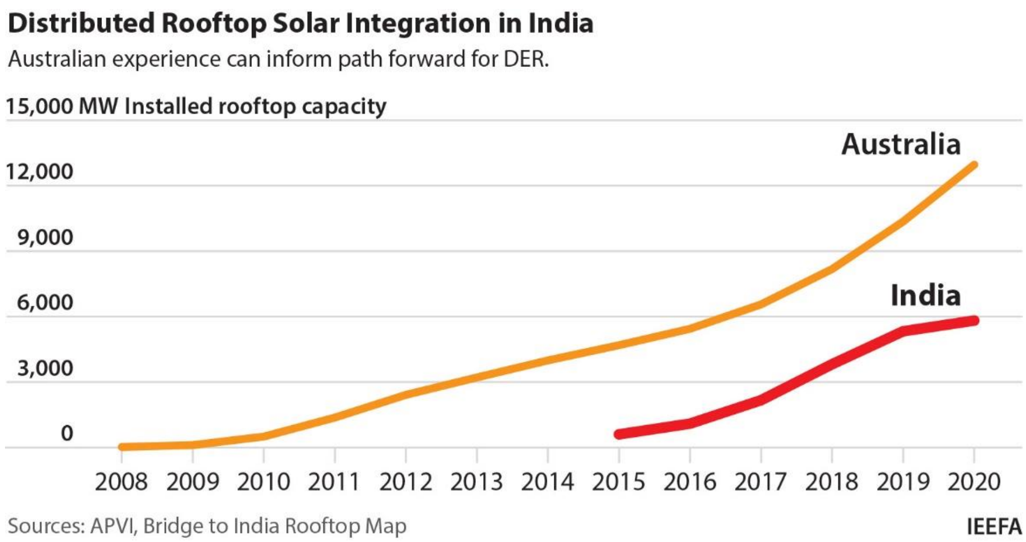
While most of the policy focus in India, as elsewhere, has been on large-scale renewable energy, the Government of India has set a target of 40 gigawatts (GW) of installed rooftop solar (RTS) capacity by 2022 to improve energy security, reduce land use strains, better strengthen the national grid, improve air quality and reduce user costs. The government has also undertaken significant measures to support the adoption of electric vehicles (EVs) and energy efficient lights and fans. State governments are also supporting the uptake of Distributed Energy Resources (DER) including rooftop solar (RTS) and solar irrigation pumps. This report puts the case that the future of RTS is rooftop solar plus storage—either in the form of batteries or electric vehicles.

For all the above reasons and more, the integration of DER is worthy of serious policy attention as an enormous opportunity for India. This report looks at what can be learnt from the integration of DER in Australia so far and how it might better inform India's investment program. We discuss technical, regulatory and market integration of DER, arguing that technical integration is the first priority. Technical integration work is vital to support consumer and investor confidence in DER in India. This encompasses the quality of DER products and installations, integration into the distribution grid and providing certainty of return on investment.

The future will be rooftop PV with battery storage/electric vehicles.

The Australian Energy Market Operator (AEMO) has established a DER Register which collects information on DER devices such as rooftop solar, batteries, EVs, air conditioners and pool pumps at the time of installation. Australian distribution businesses have been trialling a number of technologies and data sources to give them greater visibility of low voltage (LV) networks. Greater visibility of LV

networks, including through smart meters or equivalent devices is important for the efficient and effective management of multi-way flows.



Ensuring up-to-date technical standards are in place for technologies such as inverters, EV charging and appliance demand response is vital. These standards are best set in a way that involves industry, consumers, distribution businesses, Original Equipment Manufacturers (OEMs), the system operator (POSOCO), the Ministry of Power and others. In Australia quality control of solar modules and installations has been regulated via subsidy schemes.

Probably the most important innovation in managing DER in Australia has been the development of dynamic operating envelopes (DOEs) which vary import and export limits over time and location, based on the available capacity of the local network or power system as a whole. Indian distribution companies (discoms) could look at developing the capacity to create DOEs, particularly in leading areas of growing RTS penetration.

In planning for DER integration, policy makers and discoms should be wary of scaremongering about the technical impacts of DER. This report details the example of how there have been considerable concerns about the potential for RTS to cause significant voltage rises on the distribution networks in Australia. Speculative concerns have not been borne out by quantitative analysis or real-world experience. India can learn to watch out for these spurious arguments and try to leapfrog into a system where DER is central, planned for and taken advantage of.

In terms of regulatory integration of DER, energy efficiency comes first to optimise the return on any investment in on-site generation or storage. Australian policies, especially for minimum efficiency standards for rental properties and minimum energy performance standards and compulsory labelling of the energy efficiency of appliances, lighting and equipment are worth noting—particularly given the expected urbanisation of the Indian population over the coming two decades.

A wholesale demand response mechanism (DRM) will commence in Australia in 2022. Demand response will need to be in a different form in India given that only a still small volume of electricity generation is traded in the real-time market, but nevertheless, it needs to be a priority for policy makers and discoms to assist in the optimal development of a national electricity market. The increase in air conditioning load predicted for India by the International Energy Agency (IEA) suggests that a clear price signal is key to ensuring demand-responsive air conditioners and converting existing air conditioners to be able to be remotely controlled by a discom is a policy ripe for development.

India can leapfrog into a system where DER is central, planned for and taken advantage of.

Next, data regulation is important, especially where consumers are able to own and easily access their data for use in choosing services or purchases, such as RTS. The introduction of a time-of-day pricing signal would be valuable because consumers could use data directly or through a third-party to vary/optimise their demand.

Performance-Based (or outcomes-based) Regulation (PBR) is a means to align the objectives of the network owners with the social and decarbonisation policy objectives and is well suited to DER integration. Australia has yet to move to PBR but has a multi-year revenue cap for discoms which could be considered for India. Other outcomes that could be contemplated for Indian discoms are promoting discom-led RTS, solar+storage and RTS+EV offerings, and financing discoms to develop EV charging stations at the most appropriate locations in their grids.

Complementary to PBR is innovation funding. The Australian Renewable Energy Agency (ARENA), similar to the Indian Renewable Energy Development Agency (IREDA), has developed a Distributed Energy Integration Program (DEIP) which has been very helpful in catalysing DER-related research, trials and policy development.

Finally, for market integration of DER policy makers should endeavour to keep a relatively steady rate-of-return for RTS and batteries as installation and financing costs fall and circumstances change.

Innovative financing models such as the First Loss Portfolio Guarantee (FLPG) and the Partial Risk Guarantee Fund should be explored as alternative mechanisms to de-risk the sector. IEEFA recommends that the Indian banks and financial institutions enhance the disaggregation of their portfolios between thermal and renewable energy assets and have separate lending allocations. Further, within the renewable energy sector, separate allocations should be provided to RTS and small-scale storage/EVs. In addition, banks should give concessional loans to RTS as the market is small and still needs financial support, leveraging the existing US$625m investment program of the World Bank and the State Bank of India (SBI) which is nearing the end of its five-year mandate.[1]

As the Indian duck curve develops, time-of-day tariffs could be an increasingly useful tool for balancing demand with increased low cost but variable supply.

Timely and smart technical standards are vital, especially for energy efficiency and demand response.

South Australia Power Networks (SAPN) introduced a new middle-of-the day 'solar sponge' tariff at a quarter of the standard rate from 1 July 2020. India has the opportunity to learn from the results of this and other tariff enhancements internationally, enhancing the low emissions, smart electricity grid of the future.

Likewise, there is no need for India to rush into DER aggregation policy or trials until there are higher penetrations of RTS, storage and EVs.

India has an opportunity here to learn from Australia's mistakes and successes and focus first on the most important technical and regulatory measures for DER integration.

[1] The World Bank. India Project Update: Grid Connected Rooftop Solar Photovoltaic Program. 27 February 2019.

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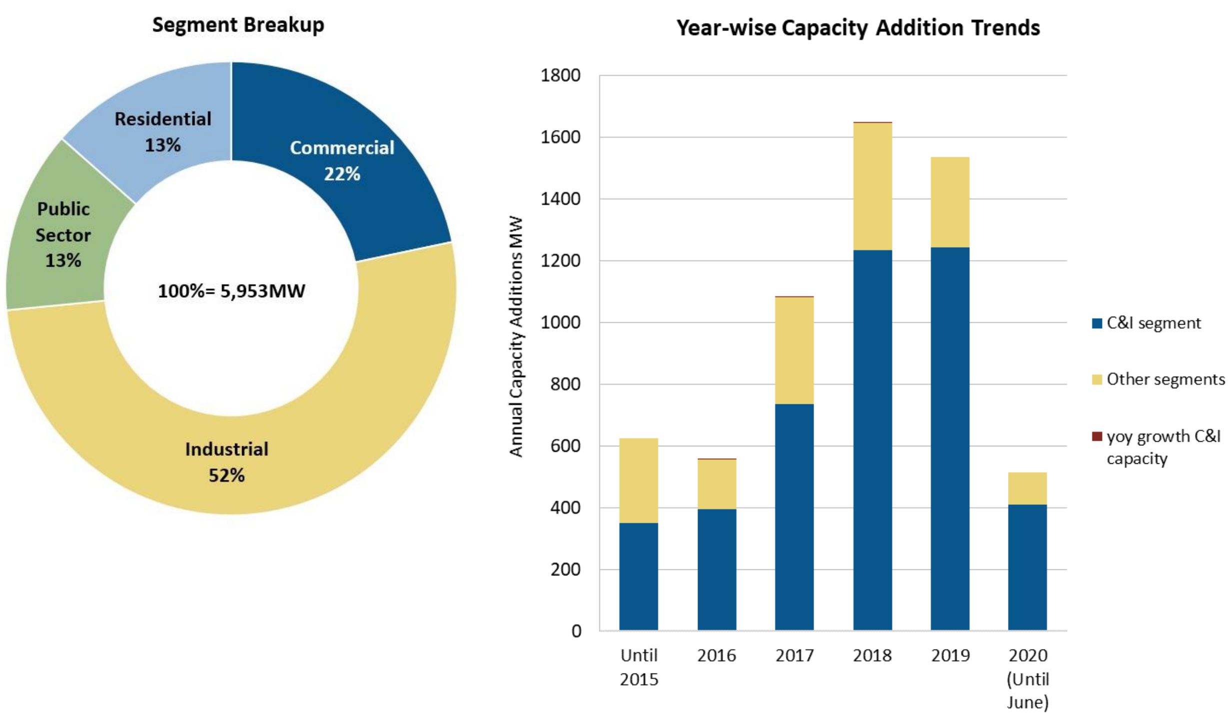
Installation of Rooftop Solar in India Vis-a-Vis Australia

The recently released IEA India Energy Outlook 2021 concludes that "India is in a unique position to pioneer a new model for low-carbon, inclusive growth". That report also states that the "Indian electricity sector is on the cusp of a solar-powered revolution",[2] an ideal opportunity to lead the developing world in decarbonisation.

India's growth in large-scale solar generation over the last five years has been impressive, reaching 39GW at the end of January 2021, equivalent to total wind capacity.[3] RTS is only one sixth of the total solar capacity at 5.9GW (as of June 2020). The Government of India has set a target of 40GW of installed rooftop solar capacity by 2022. It is currently unclear if this target will be achieved due to various factors including policy uncertainty, Covid-19 and lack of access to low cost capital.

Figure 1: Indian Rooftop Solar Installed Capacity (MW)



Source: Bridge To India Rooftop Map June 2020.

These figures comparing large- and small-scale renewables would suggest that rooftop solar in India would be of little interest to investors or policy makers. However, this report outlines numerous reasons to better leverage the significant system-wide advantages for India to accelerate the rollout of RTS together with other forms of distributed energy resources (DER), especially small-scale storage,

[2] IEA. India Energy Outlook 2021. February 2021.
[3] CEA. Installed Capacity. January 2021.

micro-grids and EVs, as well as best leveraging the value of India's 46GW of hydro-electric capacity.

There is much that can be learnt from Australia, as the country with the most RTS Watts per capita (786W per person as at the end of 2020[4]) and growing rates of small-scale batteries.

Australia now has 2.7m household rooftop solar systems with a combined capacity of over 13GW (out of a total PV capacity of over 19GW). There was a record rate of 3GW installs in the calendar year 2020 which was a 39% increase on a year-on-year (yoy) basis and the highest per capita install rate ever in the world.[5]

It should be noted that Australia's massive increase in rooftop solar installs was only a third of Vietnam's in 2020—which was an extraordinary 9GW off a very low base. Vietnam's example shows India's 40GW target is achievable with the right incentives, but it would be better for India to take a planned, more sustained approach.

Figure 2: The Extraordinary Growth in Australian Solar Installations

Source: Australian PhotoVoltaic Institute (APVI).

It is important to note that the vast majority of household RTS has been on freestanding homes in Australia. With the majority of residents in tier 1 cities in India living in apartments it is unlikely that RTS will ever be as high a percentage of households. However, there is great potential for RTS on C&I and potentially for a proportion of apartment roofs to adopt solar, especially as solar modules become lighter and/or more flexible.

[4] Author's own calculation based on APVI data.
[5] Renew Economy. Rooftop solar market ends tricky 2020 by smashing records, surpassing 13GW total capacity. 11 January 2021.

What Are the Dynamics of Distributed Energy Resources (DER)?

No one knows what the likely balance between distributed generation and large-scale renewable energy and storage is going to be in any market in the future. However, the following facts will make a difference to how the dynamics of energy markets will play out:

- When you generate on-site, as with RTS, there are no transmission, distribution or retailing costs—except of course where additional supply is imported or exported to the grid.
- Rooftop solar is already very cheap and is expected to halve again in the next three years (module costs could drop from US$20c/kW to US$10c/kW[6]) so if optimised, the daytime charging costs of a battery or EV will be very low.
- The energy business model is changing from largely opex-based legacy fossil fuel generation to capex-based renewables at a time of record low interest rates, and there is a large amount of global capital available for investment in renewable infrastructure.[7] And with rooftop solar, there's a much higher internal rate of return (IRR)/shorter payback period than almost any other form of investment available to commercial and industrial (C&I) consumers, and higher tariff paying residential customers. As such, there's the potential to leverage private sector investment for public benefit, if we get the incentives, technical standards and regulatory arrangements right.
- EVs are the future of transportation. With this form of distributed mobile storage, it makes sense to have distributed charging co-located with generation. It will be a lot more costly for households or fleet managers to rely primarily on off-site public or private charging stations than to charge the vehicles using RTS directly.
- It's also possible that eventually battery storage and solar will both become so cheap that any inefficiencies from charging a stationary battery with RTS and then discharging the stationary battery into an EV battery will be largely irrelevant.
- EVs also have huge potential to provide vehicle-to-grid (V2G) services, including relieving grid congestion and providing ancillary services (such as frequency and voltage control). V2G (or bidirectional charging) is where an EV can both charge from and discharge into the grid.

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[6] Professor Martin Green, University of New South Wales. Presentation at UNSW SPREE and The Australian Centre for Advanced Photovoltaics. How Cheap Can Solar Photovoltaics Become? 18 December 2020.

[7] IEEFA. Global capital mobilising for India's $500bn renewable energy infrastructure opportunity. 16 February 2021.

This report therefore argues that conceptually we now need to consider or plan for RTS plus storage/EVs, rather than RTS alone.

The Future is Solar+Storage (Stationary or Mobile)

Rooftop solar, while continuing to improve in efficiency, is, on its own, yesterday's technology. Solar+storage is already here and solar+mobile storage (EVs) is in the near-term future.

One of the three large 'gentailers' in Australia is offering what is effectively a seven-year rent to buy solar plus storage product—5.6kW of solar with a Tesla Powerwall 2 battery (Energy Australia's Solar Plus Plan). Combining solar with storage is now mainstream in Australia.

IEEFA has calculated that in 2021 solar+storage will be cheaper than grid supply for most C&I customers.[8] The study reveals that the levelised cost of energy (LCOE) for a 1MW rooftop solar system attached to 250kW of energy storage with a backup of four hours will be around Rs6.6–6.8/kWh by next year. This is less than the grid tariff for most C&I consumers, and well below the cost of power produced by diesel generators. Further, with tariffs moving closer towards 'time-of-day' (ToD) usage, battery storage will be increasingly economically viable for C&I consumers.

In addition, India has as much as 90GW9[9] of behind the meter diesel generators, which are mostly used as grid backup. While this represents an enormous sunk investment, the ongoing running costs are also significant as they rely on expensive imported diesel. Particularly if there are low-cost financing options, it would be expected that these diesel generators would be quickly replaced by solar+storage.

RTS and batteries may be an interim or complementary phase, soon to be replaced by solar and EVs, which have three advantages over stationary storage:

1. They have larger batteries—most new model EVs have 6-10 times the capacity of small-scale batteries.
2. They are mobile, and able to be driven to charge from different locations.
3. If charged with renewable energy, they help rapidly decarbonise the transport sector, and reduce India's enormous and growing reliance on imported oil.[10]

There's also the potential of managed charging and discharging and V2G. Depending on the nature of the grid and the need for ancillary services, this could be a game changer. There are currently about 15 million light vehicles in India, which have the

[8] IEEFA. Powering up sunshine – how India's commercial and industrial sector can drive rooftop solar power. July 2020.
[9] IEA. India Energy Outlook 2021. February 2021.
[10] Without sufficient renewable energy generation, electric vehicles can greatly assist in reducing urban air pollution but potentially at the expense of air pollution in the vicinity of coal-fired generation.

potential to be many times the power capability of utility-scale electricity generation if converted to electric and charged with renewable energy.[11] Especially in conjunction with RTS, this could provide much-needed flexibility in the Indian grid as the proportion of VRE grows.[12]

The Indian government has an ambitious target of 15% of vehicle sales to be electric by 2022, and Prime Minister Narendra Modi has a vision to be a fully electric vehicle nation by 2030.[13] The government has introduced policy initiatives such as the Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) Scheme to boost adoption of EVs. In addition, ten states in the country have announced EV policies and another six states have prepared draft EV policies.

Discoms and policy makers need to think innovatively and develop measures that increase adoption of RTS+EVs.

Discoms, Public Sector Undertakings (PSUs), municipal corporations and others are installing EV charging stations. The Central Electricity Authority (CEA) reported 933 EV charging stations had been installed in India by June 2020 (which is more than Australia has currently). Further, in November 2020, the Indian government announced plans to set up at least one EV charge point at 69,000 petrol pump locations across India.[14]

Even without harnessing private electric vehicles, there's the potential of public transport and private vehicle fleets to provide a relatively low cost means of providing flexibility. Charging and discharging can be managed to make the most of rooftop solar availability e.g. on the roofs of bus or fleet charging stations. Under its Stated Policies Scenario (STEPS), the IEA projects there will be 4.4m buses by 2040. In the U.K., U.S. and Australia, given the consolidated ownership and operation and potential flexibility of electric buses, significant trials are underway with managed charging or V2G. Learning from international experience, it would be valuable for Indian discoms, transport agencies and policy makers to start planning for the potential of electric buses combined with RTS, for example through managed charging trials.

The outcome of thoughtfully combining RTS and EVs would be greater self-sufficiency for the households and C&I consumers that adopt this combination of technologies, and eventually changes to wholesale supply costs. This could have positive or negative consequences for discoms. If discoms become suppliers of RTS+EV offerings with managed charging (or V2G when it is cost effective), they could earn revenue and reduce the risk of unmanaged charging causing unnecessary costs to the grid. Discoms could soon be able to provide cheaper supply through this

[11] Dr. Praveen Kumar, Associate Professor, Indian Institute of Technology Department of Electronics & Communication Engineering. Grid to Vehicle (G2V).
[12] IEEFA. Renewable Energy Integration: India's Next Big Challenge. 26 February 2021.
[13] Department of Heavy Industry. National Electric Mobility Mission Plan 2020.
[14] PTI. Govt to set up EV charging kiosks at 69,000 petrol pumps across India. 24 November 2020.

combination of RTS and EVs than through traditional supply, but only if both are well managed to maximise self-sufficiency behind the meter and avoid unnecessary demands on the grid.

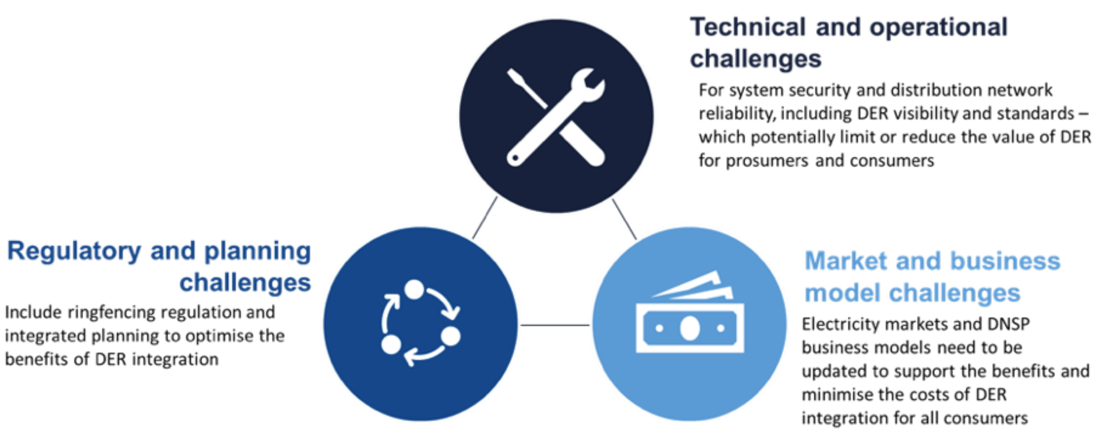
Discoms could also develop charging stations at the most appropriate locations in their grids and look to the potential of V2G to ease future grid congestion. Even if they don't sell the EVs, discoms could offer RTS+two-way EV chargers with managed charging as a packaged service, which would benefit the consumer and the grid.

Combining RTS with EVs also addresses the issue of EVs being fuelled by thermal electricity which creates emissions. So discoms and policy makers need to think innovatively and develop measures that increase adoption of RTS+EVs and change usage patterns to leverage low cost solar when it is available and enhance grid stability.

If consumers purchase RTS+EV offerings, there is the potential for grid defection (the 'death spiral') if the EV is used as onsite storage, but in a high energy demand growth market like India this can be a massive opportunity, rather than a threat, if managed properly. Alternatively, if the RTS+EV system is purchased without managed charging, it is likely to result in solar exports during the day and potentially peaky charging demand at other times. Either outcome will increase overall costs and the burden to other consumers or taxpayers.

The consequences of these dynamics are that urgent reform is needed to optimise the benefits of DER for all Indian electricity system users. In Australia, the Energy Security Board (for which the lead author worked) has developed a DER Integration Roadmap and Workplan focused around three dimensions: technical, regulatory and market. This may seem simplistic, but it is important to understand that DER integration is complex and the order of actions is important to reduce costs.

Figure 3: The Three Dimensions of DER Integration



Source: Australian Energy Security Board.

Technical Integration of DER

Technical integration of DER is the first step—it lays the foundation for ensuring DER does not impose additional costs and in fact can be used at times to reduce system costs. Technical integration work is also vital to secure consumer and investor confidence in DER. DER creates a critical change in the distribution from one-way to multi-way flows of electricity.

Technical Standards

Technical standards need to be set to support system security, distribution network operation and also the ability for DER owners to be rewarded for providing DER services. Most importantly, governance arrangements need to be established to ensure DER technical standards can be set and updated as rapidly as possible within the changing nature of the system.

Often technical standards can be grounds for conflict between the needs of manufacturers, customers, distribution businesses, system operators, regulators and aggregators. The manner in which the standards are set is critical to resolving these diverse views and ensuring that market evolution does not get bogged down in endless technical discussions or that the needs of one market player dominate outcomes. Examples of DER technical standards that need to be set in a timely manner include:

- Inverter standards, including for frequency and voltage-disturbance ride through
- Demand response standards for appliances
- Interoperability/communication/data standards to allow access to data and potentially upgrades, communication with and control of devices or systems, for example by aggregators
- Cybersecurity standards
- EV connection and charging standards
- V2G standards (note a new ISO 15118-20 vehicle-to-grid (V2G) communication interface standard will be released this year enabling bidirectional power transfer for multiple cars).[15]

Australia is in the process of addressing these challenges with a proposal being considered by the rule maker, the Australian Energy Markets Commission (AEMC), to put initial DER technical standards into the National Electricity Rules. The Energy Security Board (ESB) has also lodged a separate rule change for new governance arrangements for setting technical standards. The proposed governance arrangements include a standing DER technical standards committee consisting of experts from industry, consumers, distribution businesses, Original Equipment

[15] Virta Global. Vehicle-To-Grid: Everything You Need to Know.

Manufacturers (OEMs), the system operator and others advising on a vision and forward standards workplan.

A related issue is the need for accredited installers and products to ensure quality. In Australia regulations for solar installers and modules are determined via the requirements of national government subsidy programs and implemented by the Clean Energy Council[16] and state subsidy schemes.[17] It is important of course that there are appropriate quality controls and consumer protections.

Governance arrangements need to ensure DER technical standards can be set and updated as rapidly as possible.

In November 2020, the Indian government approved Rs4,500 crore (US$603m) for 'High Efficiency Solar PV Modules' to the nodal Ministry of New and Renewable Energy (MNRE) under the Production Linked Incentive (PLI) scheme. A focused PLI scheme for solar PV modules will incentivise domestic and global players to build large-scale solar PV capacity in India, giving a much-needed boost to the manufacturing sector and helping attain Prime Minister Modi's goal of 'Aatmanirbhar Bharat', or a self-reliant India. It is important that under the PLI scheme, quality standards for solar PV products are maintained. Learning from the Australian governance arrangements, technical standards should be put in place and a respected agency appointed to ensure compliance.

DER Visibility

In addition, where possible, DER devices and systems need to be visible to discoms. There's a need for static visibility—where the DER devices are on the network—and more dynamic visibility to assess the interaction between the network and the DER.

In Australia, the Australian Energy Market Operator (AEMO) has established a DER Register which collects information from electrical contractors and solar installers at the time of the DER installation.[18] Data on DER devices such as rooftop solar, batteries, electric vehicles, air conditioners and pool pumps must now be provided to AEMO's DER Register within 20 days of system commissioning or activation. The Register went live on 1 March 2020 and AEMO made aggregated data by postcode publicly available from January 2021.

Dynamic visibility is more challenging and is being addressed in different ways by different distribution businesses:

- In the state of Victoria, all connections have smart meters so the distribution businesses have easy access to 15-minute interval data.

[16] Clean Energy Council. Installers and Approved Modules.
[17] e.g. Solar Victoria. Approved Products.
[18] See AEMO: Distributed Energy Resource Register.

- In some businesses, additional monitoring devices have been installed in the network (e.g. SAPN[19] and Energy Queensland[20]).

- In the Essential Energy network in the state of NSW, a trial is underway to access data from broadband kiosks at five-minute intervals to provide significantly improved visibility of the network's 'vital signs'. The trial has already provided vital insights concerning voltage on the Essential Energy network.

It is not necessary to have 'real-time' data to manage DER in distribution networks and it is not even necessary to have data from each connection point. What is required to make DER a success is sufficient visibility to manage the distribution network.

Dynamic Operating Envelopes

Probably the most important innovation in managing DER in distribution networks in Australia has been the development of dynamic operating envelopes (DOEs), sometimes known as dynamic connection agreements, which vary import and export limits over time and location based on the available capacity of the local network or power system as a whole. Previously distribution network businesses have been managing solar exports through the imposition of static export limits (usually 5kW for households), despite the growing size of household PV systems (now averaging 9kW). This blunt instrument, while useful for incentivising self-consumption, limited the return on investment and resulted in inefficient solar spillage, especially on sunny days with households that weren't at home during the day.

In the case of South Australia (SA) Power Networks, DOEs are set dynamically at five-minute intervals, 24 hours in advance for each connection point (see Figure 4). In a Virtual Power Plant (VPP) trial across 1,000 batteries, this has enabled the 5MW capacity to be increased to a possible 10MW, while keeping the network operating safely and securely.[21]

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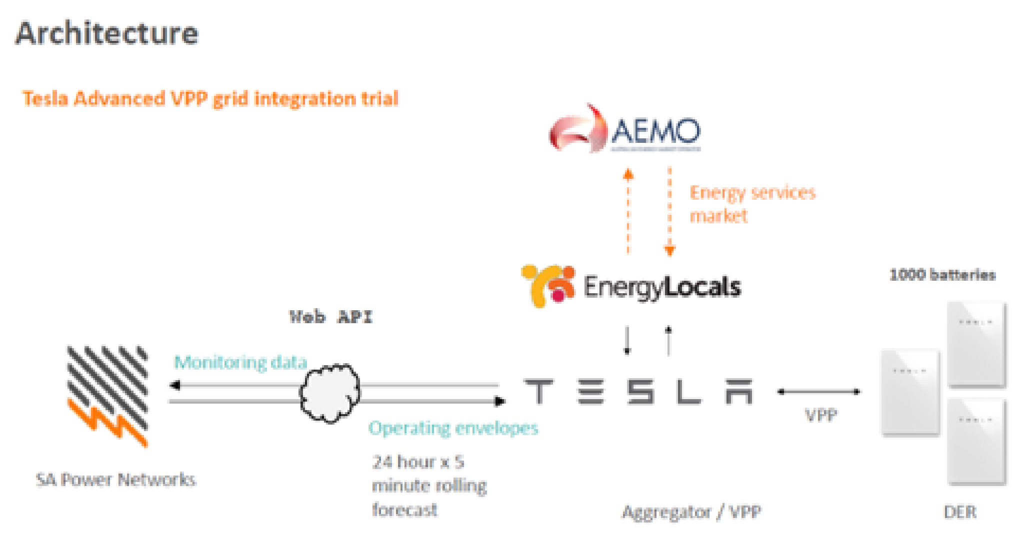
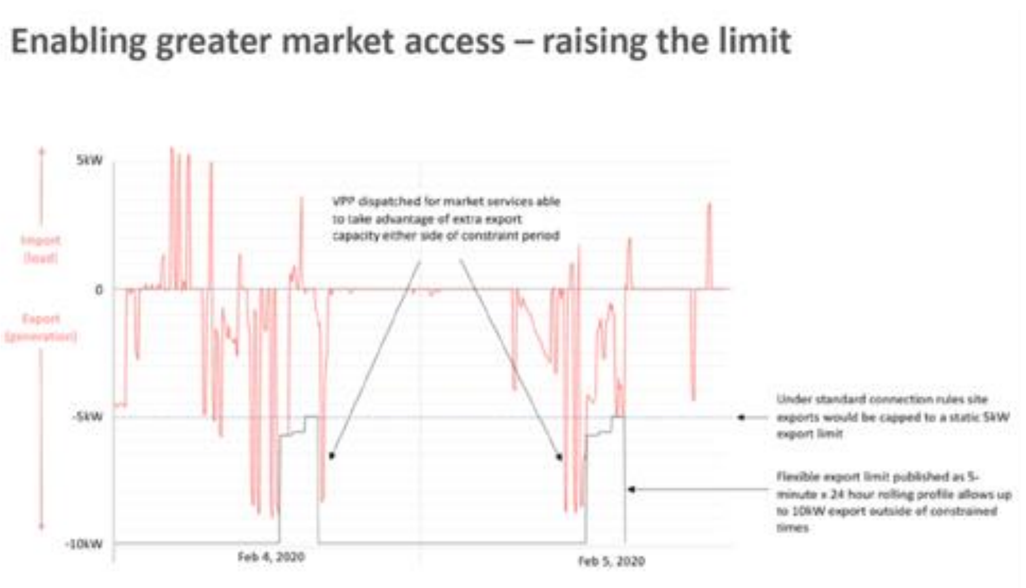
[19] SA Power Networks. LV Transformer Monitoring Business Case. 10 December 2019.
[20] Energex. LV network monitoring trial.
[21] See ARENA. Advanced VPP Grid Integration.

Figure 4: Architecture of SA Power Networks Operating Envelopes and VPP Trial



Source: SA Power Networks.

Figure 5: How Dynamic Operating Envelopes Can Increase Exports Within Network Constraints



Source: SA Power Networks.

A partnership of regulatory, industry and academic organisations has been formed to examine how to support national consistency for fair and equitable DOE allocations, standardisation of customer connection agreements, information and market process and monitoring and enforcement. This work is being supported by the Australian Renewable Energy Agency (ARENA).[22] It will take some time to complete, but what is most important is to ensure the implementation of DOEs is a positive consumer experience.

DOEs can provide the solution to multiple concerns about DER installation such as exports causing voltage rises on the network, resulting in reverse flows beyond substation limits. They also address system operator concerns about minimum demand resulting in an unstable system, without sufficient load, for example to restart in the advent of a blackout.

Most importantly, DOEs can be developed and implemented at relatively low cost, especially in comparison to network infrastructure solutions to these concerns. SA Power Networks has spent an estimated $32 million of CAPEX over the 2020-25 period to build the capabilities to roll out DOEs or 'flexible export limits' as a standard connection service in South Australia. Bryn Williams from SA Power Networks notes that, 'the cost for any given (distribution business) is likely to be different from any other, depending on their specific circumstances and their starting point in terms of existing systems and capabilities. In SA Power Network's case this involves significant investment in:

'New IT systems to receive and process high volumes of telemetry data from smart meters and other data sources across our LV network, whereas the Victorian distribution businesses have built this kind of data platform for their AMI (Advanced Metering Infrastructure) rollouts

Building our LV hosting capacity model, which includes the cost of field audits on a sample basis to improve the quality of data we have on the physical assets we have in the field for our LV network, as our records and data quality in this area are poor

The cost of establishing a DER database and associated business processes.'[23]

Technical Scaremongering

A lesson from the Australian experience of technical integration of DER is that concerns about DER's impact on the grid can be exaggerated and solid data and trials are needed to ensure that risks are not overstated and excessively costly solutions are not put in place to manage them. For example, there have been considerable concerns about the potential for RTS to cause significant voltage rises on the distribution networks, such that voltage limits will be breeched. There was a lot of speculation about the extent of this issue and of the associated issue of the extent of losses to prosumers from high-voltage curtailment of inverters (which in Australia occurs at 253V).

The ESB commissioned a study examining the state of voltage across the National Electricity Market (NEM).[24] The data analysed by the University of New South Wales

[22] ARENA. Dynamic Operating Envelopes Workstream.
[23] Pers. comm.
[24] See Energy Ministers: LV Voltage Report.

(UNSW) showed that, even in the absence of RTS, there is a significant level of high voltage across all distribution networks in all regions of the NEM (Figure 6).

Figure 6: Samples of Average Suburban Voltages in Australian NEM Regions

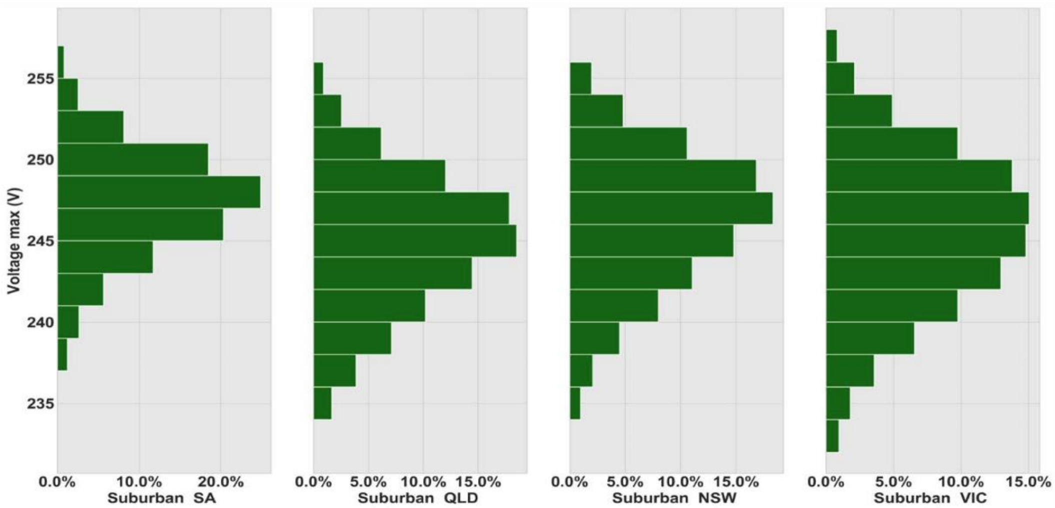


Figure Source: UNSW.

The nominal voltage standard in the NEM is 230V—more than 95% of readings were found to be higher than this level. Minimum voltages at most sites in most regions, seasons and times of day are generally above the 230V nominal standard. Maximum voltages recorded are generally towards the upper bound of acceptable voltage in all distribution networks, in all seasons for all daily hours. In South Australia, average maximum voltages frequently sit near the upper bound of 253V over the entire year, although they are generally highest in autumn and spring, when state demand is typically lower and PV performance is relatively good. This is particularly significant given that South Australia has a penetration of over 40% RTS.

These voltage issues are due to a range of factors, especially historic circumstances of distribution network operation, i.e. to support additional air conditioning loads installed over the last three decades and an historic 240V nominal standard, from which Distribution Network Service Providers (DNSPs) are still transitioning.

In light of these findings, it is clear that the operation of the distribution networks is at issue, not rooftop solar. Yes, RTS can contribute to voltage rises, but in the Australian case any contribution is not particularly significant at this point. In fact, the UNSW analysis found that many sites experience higher voltages during the night.

Somewhat surprisingly, even though the voltage measurements are significantly above what would be expected given the voltage regulations, revenue losses due to curtailment, are very small on average: approximately $3–$12 per year per site, assuming a 5kW system (noting that the UNSW analysis only considered clear sky days and that further work is required). There are a small number of prosumers that are significantly impacted, with the most impacted prosumer estimated to lose approximately in the order of 30-90% per year. In most of the cases, the problem is able to be rectified by the network operator, for example, through transformer tap changes.

This voltage example illustrates two features of how DER has been approached and discussed in Australia and provides salutary lessons for other countries following in their footsteps. Despite—or perhaps because of—the popularity of RTS with Australian consumers, the energy market institutions and existing large-scale interests have tended to frame DERs as DEPs, or Distributed Energy Problems (to use Mark Paterson's phrase[25]), and viewed DER as a sideline to large-scale renewables.

As a result, there has been scaremongering about a number of risks, in particular: voltage rise, reverse flows and minimum demand. In each of these cases, DER are not seen as an opportunity to improve the system or to think differently about how to manage the system. As with renewables in general, there have been warnings that the system will cease to operate or be unable to operate without large expensive changes.

Such scaremongering has not been borne out by experience, distribution businesses have innovated at relatively low cost (such as developing operating envelopes) and consumers are enjoying the benefits of falling power bills, both those with RTS and those without (due to falling wholesale prices from large and small-scale renewables). India can learn to watch out for these spurious arguments and try to leapfrog into a system where DER is central, planned for and taken advantage of to the benefit of the entire national grid system.

Regulatory Integration of DER

Alongside the technical dimension, there are regulatory changes that are required to optimise the benefits of DER to consumers and the system.

Energy Efficiency First

Given the weather dependence of both small- and large-scale solar and wind, we are moving towards a more variable supply scenario, which can ideally be matched by variation in demand. Instead of the historic legacy convention of supply following demand, the energy transition should be towards a smart grid where demand follows low cost supply, which means we need to have more sophisticated demand response measures.

Energy efficiency always needs to come first—and will increase the return on investment (ROI) on any onsite investment in RTS or storage. There are major

[25] See Mark Paterson LinkedIn.

opportunities in both Australia and India for improving building and appliance energy efficiency.

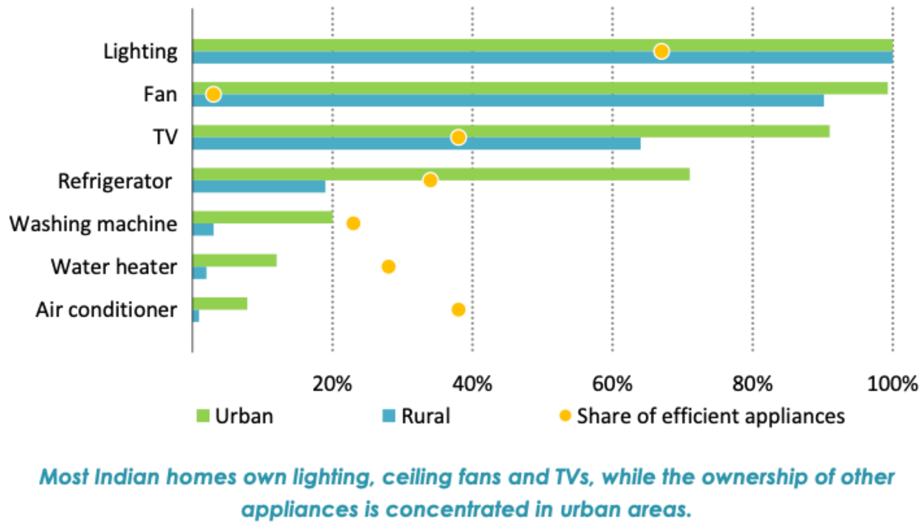
Australia has long had a thermal performance star rating system for new residential buildings, the Nationwide House Energy Rating Scheme (NatHERS), but the regulatory requirements are generally much lower than global best practice (6 stars where California has an equivalent 8-star standard). The existing building stock continues to be a major issue and only recently has the state of Victoria announced funding for energy upgrades of social housing properties (A$112m) and new high efficiency heating and cooling systems for low-income households ($335m). The Victorian government is also introducing minimum efficiency standards for rental properties, which is a critical new regulation impacting the electricity and gas bills of significant numbers of low-income tenants.

India has shown remarkable progress in implementation of energy efficiency measures. The government can introduce regulations for energy efficiency standards in new buildings and for rental properties. This will help India accelerate its goal of energy efficiency as urbanisation increases.

India has shown remarkable progress in implementation of energy efficiency measures.

Large-scale programs for what the Americans call 'weatherisation' could be considered for India, especially as they can create significant numbers of jobs. With 270m people expected to move to Indian cities over the next two decades, high and increasing standards under Eco-Niwas Samhita, the energy conservation code for residential buildings, will pay dividends in reduced bills and lower greenhouse gas emissions.

Figure 7: Percentage of Indian Households Using Appliances, 2019



Source: IEA based on Agarwal et al (2020).
Note: Efficient appliances are those with 4 or 5 stars on India's standards and labelling program, except for lighting where it refers to LEDs.

After the building fabric, lighting is the next priority for energy efficiency. Australia banned incandescent bulbs in 2009[26] and halogen bulbs from 2020 in line with EU standards.[27]

In 2012 under the National Mission for Enhanced Energy Efficiency, the Bureau of Energy Efficiency (BEE) launched perform, achieve and trade (PAT) scheme. The aim was to improve the energy efficiency of large-scale industries and create a market-based mechanism to incentivise energy savings by converting these savings to a tradable instrument. The scheme was a big success, resulting in industries exceeding their energy savings target by ~30% and an emissions reduction target by ~35% during the 2012-2015 period.[28] The scheme was extended to other sectors in Phase 2 and has been instrumental in reducing energy consumption and thereby emission in the industries.

The Indian government Unnat Jyoti by Affordable LEDs for All (UJALA) program launched in 2015 to provide 770 million LED bulbs to replace incandescent bulbs is a great example of energy efficiency leadership. So far 367 million LEDs have been distributed, and the LED Street Lighting National Program has resulted in the installation of over 10 million LED smart streetlights by the Energy Efficiency Services Limited (EESL), a government-owned energy services company.[29]

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[26] energyrating.gov.au. Lighting Phase Out.
[27] On 20 April 2018, the COAG Energy Council agreed to further improve lighting energy efficiency regulation by phasing out inefficient halogen light bulbs in Australia and introducing minimum standards for LED light bulbs in Australia and New Zealand in line with European Union (EU) standards.
[28] PowerLine. PAT Success: Energy Efficiency Scenario Improves. February 2018.
[29] IEA. India Energy Outlook 2021. February 2021.

Further, EESL introduced 5-star-rated fans, offering consumers an opportunity to reduce electricity bills by half by replacing inefficient fans and lamps. So far 2.3 million energy-efficient fans have been distributed. In February 2019, EESL launched the Super-Efficient Air Conditioning (AC) Program for residential and institutional consumers in the Delhi discom area. Such ACs are 40% more efficient than the 3-star ACs currently available in the market, but are priced comparably. EESL is working towards making this program and its benefits available to all consumers across the nation with the other discoms likely to partner with EESL in future.

The UJALA program is a great example of energy efficiency leadership.

Australia has found minimum energy performance standards and compulsory labelling of the energy efficiency of appliances, lighting and equipment to be highly cost-effective. The Greenhouse and Energy Minimum Standards (GEMS) Act was put in place in 2012, creating a national regime for product energy efficiency with a new national GEMS Regulator replacing previous state regulators. A review of the Act in 2019 found that "the GEMS Act is achieving its purpose of providing a streamlined nationally-consistent approach to appliance energy efficiency while effectively reducing energy use, power bills and greenhouse gas emissions[30]". However, Japanese standards are still higher and worth emulating.

India has a standards and labelling program that has been operated and managed by the Bureau of Energy Efficiency since 2006. The major opportunity in both Australia and India is to continue to raise minimum standards through regulation.

India already has tasted success in replacing old inefficient lamps with LEDs and to some extent fans. India should now aggressively expand to other household appliances like refrigerators, air coolers etc. This would encourage peak shaving and also reduce carbon emissions.

The government should also promote electric cooking and provide energy-efficient electric stoves. That would help households, especially in rural areas, to shift away from conventional, more polluting fuels and reduce greenhouse gas emissions.

Demand Response to Lower Overall Cost

The Australian NEM was designed with demand response in mind but it was not until June 2020 that a rule was made whereby consumers will be able to sell demand response in the wholesale market either directly or through specialist aggregators for the first time. When the wholesale demand response mechanism

[30] Energy.gov.au. Greenhouse and Energy Minimum Standards (GEMS) Act Review – Final Report. 2019.

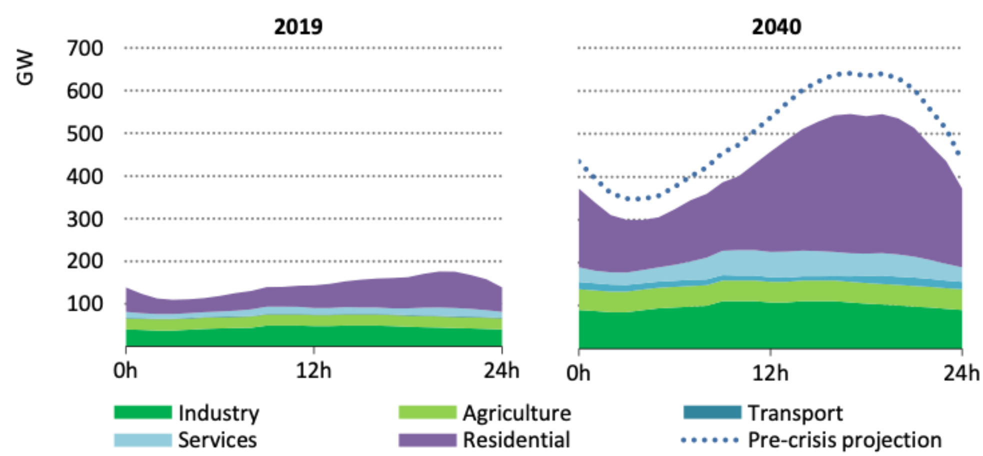
(DRM) commences in 2022, only C&I customers will be able to participate, but it is hoped participants will expand to include households in future. This is currently being explored through the post-2025 market design concept of a 'two-sided market'.

Clearly with India only having established a real-time wholesale spot market in 2020 and this only accounting for a small proportion of electricity traded, a wholesale demand response mechanism would not be appropriate. The question then is how to enable demand response at scale in India? And where are the largest gains likely to be made?

Due to global heating and increasing wealth, sales of air conditioners are expected to grow faster than any other area of demand. Under the IEA's STEPs scenario, air conditioner stock will grow from 30 million today to 670 million in 2040; this six-fold increase will mean Indian air conditioning load is the equivalent to the entire German demand by 2040.

The India Cooling Action Plan (ICAP) launched in 2019 adopts the principle of "thermal comfort for all", with a target to reduce cooling energy requirements by 25-40% by 2037-38, but the IEA notes that "the precise nature of this commitment is not clearly defined".

Figure 8: Changing Daily Electricity Demand in India 2019 and 2040



More than half a billion air conditioners and fans are purchased by 2040 in the STEPS, significantly raising the evening peak, although not as high as in pre-crisis projections.

Source: IEA.

One area for India to consider therefore is the potential for demand response for air conditioning.

The Energex PeakSmart air conditioning program[31] in south east Queensland provides households, businesses, builders, developers, retailers and traders with

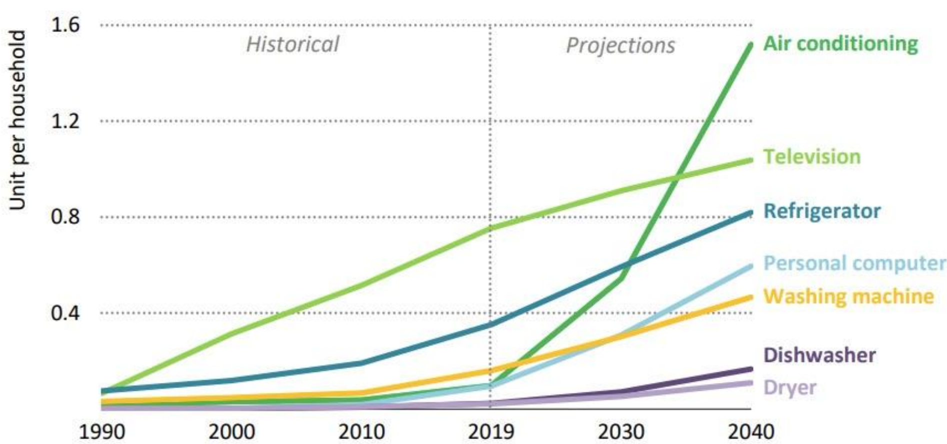
[31] Energex. PeakSmart air-conditioning.

financial incentives of up to $A400 for purchasing and installing a demand-responsive air conditioner or converting an existing air conditioner to being able to be remotely controlled by the discom. Such remote-control programs will become more cost effective as the afternoon-evening peak increases (as in Figure 8).

Similar demand-response measures could also be applied to agricultural pumping in India. Alternatively, these loads could be moved to times with greater availability of supply and network capacity.

Co-location of solar with pumps is already underway. For example, in Gujarat, the government introduced the Suryashakti Kisan Yojana (SKY), a pilot project to enable 12,400 farmers in 33 districts of the state to generate solar power—and to use part of that power for irrigation while selling the surplus to the grid for Rs7/kWh (US$0.10) for seven years and Rs3.50/kWh (US$0.05) for the remaining years. Such incentives help farmers to manage their demand and provide the energy during peak hours. The introduction of time-of-day tariffs for agricultural consumers would help farmers provide the much-needed demand response and deliver cost savings to discoms by avoiding buying expensive power.

Figure 9: Appliance Ownership in Indian Households in the STEPS Scenario



Source: IEA.

Time-of-day pricing could incentivise demand response, so that should be a first step. Time-of-day pricing should be a priority where there are lumpy or non-time critical loads (like pumps). This is covered in detail below.

Time-of-day pricing could incentivise demand response.

The discoms will need to develop significant capacity in demand management and demand response. They do not necessarily need to undertake the works themselves and may benefit from use of competitive tendering for such 'non-network solutions'.

Models like Farmer Enterprise (FE)/village-level enterprise or Private Developer (PD) could be explored. In the FE model, the enterprise is responsible for the implementation of solar irrigation and the distribution of solar pumps among its members. In the PD model, a discom can invite private players to install a solar power plant, which would supply electricity to the discom or a renewable energy buyer.

The Importance of Smart Meters or Equivalent Technology

The Indian government plans to replace 250 million analogue meters with smart meters across India over the next three years.[32] There is a great need for better data to better manage distribution networks with higher penetration of DER. However, smart meters are only one of the means to achieve this—and are not necessarily the least-cost option. Therefore the government should consider including as an alternative to smart meters, appliances or devices that offer a cheaper means of recording electricity flow data.

Careful consideration must be given to what the data needs are, the organisations that will use the data and for what purposes, and who pays. Australia is still struggling with these issues and the Energy Security Board is developing a Data Strategy to manage changing data needs during the energy transition.[33]

One of the four pillars of the draft strategy is new data governance—legislation that supports a clear, consistent, principles-based approach. As part of this it is vitally important that consumers are able to own and easily access their data, which is not the case currently. If consumers can share their data, they can access and compare services.

While this is currently not a priority for most Indian households, as ownership of electric vehicles grows, it will be increasingly important to ensure consumers can access competitive services and that providers can manage demand by time of day, with the introduction of time-of-day pricing. Similarly, it would be useful if the smart meters or devices supported automated controls for demand response and/or changes in exports and imports in response to price signals.

Revenue Regulation

The regulations providing rules or benchmarks to determine tariffs for discoms are worthy of reports in their own right (see 'India's Power Distribution Sector Needs Further Reform' and 'The Curious Case of India's Discoms'[34]).

[32] IEA. India Energy Outlook 2021. February 2021.
[33] Energy Security Board. Data Strategy consultation paper. 2020.
[34] IEEFA. The Curious Case of India's Discoms: How Renewable Energy Could Reduce Their Financial Distress. August 2020.

Putting aside for a moment the major issue of the financial sustainability of the discoms, it is suggested that the cost-plus year-to-year tariff setting process is too short-term and drives a sales volume focus by the discoms.

Australia's revenue regulation of distribution businesses requires major reform but it has been focused on setting a five-year revenue cap since 2008. Multi-year rate cases allow distribution businesses to plan and manage capex and opex and a revenue cap disaggregates the volume of electricity transported from the business's budget.

With the massive change to distribution networks due to the integration of DER and multi-way flows, the lead author has argued elsewhere[35] that there's an urgent need to move to performance-based regulation, as in parts of the U.S. and the U.K. Performance-Based (or outcomes-based) Regulation (PBR) is a means to align the objectives of the network owners (in India's case, state governments) with the social and decarbonisation policy objectives.[36]

Performance-based regulation can support decarbonisation and improved consumer outcomes.

PBR sets objectives for utility performance and ties them to revenue, based on specific performance metrics, such as achievement of government targets. To create revenue regulation suited to the challenges of renewable energy targets would mean moving not only to totex (a total system cost), but to whole system analysis; a major reconsideration of what kind of incentives are needed.

PBR includes the use of qualitative assessments which may be a valuable tool for cultural change in utilities, along with benchmarking and ex-post reviews. Regulators must be given sufficient flexibility to change their regulation with changing technological and commercial circumstances.

To move discoms to performance-based regulation requires comprehensive investigation beyond the scope of this paper but it could seek to include outcomes such as:

- Providing multi-year capped revenue determinations
- Putting DER on an equal footing in comparison with other forms of investment by discoms
- Promoting discom-led RTS, solar+storage and RTS+EV offerings, preferably delivered through competitive tenders

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[35] Dr Gabrielle Kuiper, The Future of Electricity Networks. 2019.
[36] Ibid.

- Financing discoms to develop charging stations at the most appropriate locations in their grids
- Supporting innovation and technology upgrades to allow discoms to manage multi-way flows.

Potentially there could be a shift to higher tariffs for households that install solar. While this would reduce the payback period, it should be done as a gradual increase over time during the initial years after installation. Feeding back into the grid when the solar generation could be used on site is inefficient and increases costs for everyone due to the unnecessary use of the distribution system. This is one of the ways through which the issue of under-recovery from residential consumers could be addressed. IEEFA has noted previously that current subsidies for under-pricing of electricity must be restricted to consumers who are most in need, in part so the discom sector can move to financial viability, and so all consumers have a more viable price signal.[37]

Innovation Funding

To manage the multi-way flows resulting from the deployment of distributed energy resources requires a substantial transformation in the operation of distribution networks. As highlighted in the technical integration section of this report, discoms need to develop new capacities in network monitoring and management and innovation funding will be required to support this. This funding is small in comparison, for example, to the billions that are needed for investment in transmission infrastructure expansion. However, any innovation funding program needs to be well designed to provide the right incentives for digitisation and smarter network management.

In Australia, the Australian Renewable Energy Agency's (ARENA) Distributed Energy Integration Program (DEIP) has been very helpful in catalysing research, trials and policy development.[38] What has been particularly helpful is the fact that the DEIP has been governed through cooperative relationships between ARENA, energy market institutions, peak distribution and consumer bodies and academics/researchers. ARENA has funded projects across dynamic operating envelopes, virtual power plants, demand response from DER and technology development.[39]

The U.K. has been even more generous in its support for distribution network innovation with a regulated Network Innovation Allowance (NIA)[40] and an Electricity Network Innovation Competition (NIC). An annual £70m funding round for 'the development and demonstration of new technologies, operating and commercial arrangements' to 'help all network operators understand what they need to do to provide environmental benefits, reduce costs, and maintain security as

[37] IEEFA. The Curious Case of India's Discoms: How Renewable Energy Could Reduce Their Financial Distress. August 2020.
[38] ARENA. Distributed Energy Integration Program.
[39] ARENA. Projects.
[40] ofgem.gov.uk. Electricity Network Innovation Allowance.

Great Britain (GB) moves to a low carbon economy'.[41] The NIA and NIC followed a £500m Low Carbon Networks (LCN) Fund to undertake trials of new technology, operating and commercial arrangements which the regulator Ofgem operated between 2010-2015.

Market Integration of DER

Need for Consistency in ROIs

Australia has been on a 'solarcoaster' with solar feed-in tariffs, which is not to be recommended. Solarcoaster is the term coined for the rising and falling of solar installations as subsidies and rates of feed-in tariffs have changed.

In Australia, state government subsidies have varied dramatically over time from highs of a gross A$0.40/kWh (US$0.30/kWh) and net A$0.66/kWh (US$0.50/kWh). The rates are now generally set by retailers, averaging A$0.06-0.12/kWh (US$0.05-0.09/kWh) but there is huge variation in the rates, with the price sometimes being zero. The investment uncertainty has caused difficulties for investors, installers and consumers. It is not recommended that India follow Australia's example in this regard.

Maintaining an average five-year payback period would assist the development of a rooftop solar industry in India.

For a smoother transition, policy makers should endeavour to keep a relatively steady rate-of-return as installation and financing costs fall and circumstances change. A five-year average payback period would provide a sufficient ROI to encourage households to adopt the technology. The pathway/rationale for tariff changes needs to be clear; for example, so that developers know that the changes will keep the payback period at or below five years as module costs and/or financing costs fall.

The IEA's 'Unlocking Rooftop PV in India' provides a series of thoughtful recommendations for achieving faster deployment of RTS, most of which relate to financing. Under 'optimizing net- and gross-metering rules', the IEA recommends ensuring an 'attractive return of investment in all consumer segments and promoting self-consumption through designing new remuneration rules'.

The Australian experience reveals that net metering is helpful in maximising self-consumption. This optimises the value of generation onsite and reduces multi-way flows. The falling cost of storage and electric vehicles makes it more important that ways are found to promote self-consumption.

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[41] ofgem.gov.uk. Electricity Network Innovation Competition.

Even with high returns, the IEA's additional areas of finance reform, including 'increasing involvement of public institutions in providing affordable loans and guarantees, standardising RTS loan application and assessment processes and simplifying rules of sectoral lending programs' and 'streamlining disbursement of direct subsidies and overall investment process for small RTS' are much needed as complementary measures.

More could also be investigated in terms of innovative financing models such as impact investing or the role of non-banking financial companies. In previous reports, IEEFA has noted that the First Loss Portfolio Guarantee (FLPG) and Partial Risk Guarantee Fund could be further highlighted as alternative mechanisms to de-risk the sector and allow access to funding first loss portfolio guarantor.

The Indian banks and financial institutions have huge exposure from lending to thermal assets, thereby exhausting their limits. IEEFA recommends the banks disaggregate their portfolios between thermal and renewable energy assets and have separate lending allocations. Further, within the renewable energy sector, a separate allocation should be provided to RTS. In addition, banks should give concessional loans to RTS as the market is small and needs financial support.

The Central Electricity Regulatory Commission (CERC) could give a fillip to the sector by having a separate Renewable Procurement Obligation (RPO) for RTS and RTS+storage/EVs. This would push discoms to deploy DER resources as currently the focus is on grid-scale RE. Also, including RTS in the Renewable Energy Certificate (REC) market would make it attractive for consumers to install such systems.

Start With Time-of-Day Tariffs

Figure 8 shows how dramatic the Indian duck curve is expected to become by 2040. The evidence from Australia suggests that households are largely unresponsive to cost-reflective network pricing. This in on account of various factors, especially the fact that retailers do not need to set cost-reflective tariffs, the overall high wealth of Australian households and the lack of automated means to respond to price signals. India will be able to learn from Australia's experience, especially with the ability to set tariffs that encourage demand to follow supply and potentially, the ability to support automated controls for demand response with smart technology roll-outs.

South Australia Power Networks (SAPN) introduced a new 'solar sponge' tariff from 1 July 2020. From 10am to 3pm, electricity network charges are now 25% of the standard rate (3.6c/kWh cf 18c/kWh peak). This should encourage consumers to use more electricity in the middle of the day when there's plenty of solar generation. However, there are a couple of challenges with this mechanism. The most obvious one being that the 'solar sponge' tariff applies every day, regardless of the weather and therefore the solar generation. Second, it is unclear as to how much load is available to be shifted to the middle of the day, especially through easy automated means.

India can wait and see how the 'solar sponge' tariff mechanism unfolds in Australia before replicating it in India. However, it can start with trialling time-of-day tariffs for C&I and residential consumers.

Consider Possible Aggregation When the Time Comes

Ever since the New York Public Service Commission proposed Distribution System Operators (DSOs) manage a 'local' market platform trading capacity, ancillary services and grid support (such as fault response) from DER, there's a big focus on how DER might be aggregated and participate in markets. Virtual power plant trials are underway in Australia and in particular, DER is being aggregated to participate in the currently highly profitable Frequency Control and Ancillary Services (FCAS) markets.

However, the long-term picture of DER market participation is unclear. A number of dynamics are in play. With falling costs of storage and EVs, it's likely that households and C&I owners of RTS will opt for greater self-sufficiency. The profitability of participating in the FCAS markets is likely to only be temporary, especially as more and more large batteries come on-line. Market participation involves substantial costs for RTS owners—they need to have hardware and software to respond to price signals and a relationship with an aggregator who must currently partner with a retailer to be able to participate in wholesale or FCAS markets. As a result, most of the VPPs are subsidised through ARENA and/or other government grants[42] or where wealthy RTS owners have already invested in the hardware, software and an aggregator relationship to maximise the use of the RTS and, usually a battery as well. (Household solar+storage currently has a payback period of over ten years, so these are not economic decisions).

Given the relatively low penetration of RTS in India, it would be wise not to spend substantial time or funds considering market integration of DER. India has an opportunity here to learn from Australia's mistakes and successes and focus first on the most important technical and regulatory integration needs.

[42] A recently announced trial of a VPP in Western Australia is being subsidised at an initial cost of $70,000 per household.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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