Distributed Renewable Energy Generation in Tamil Nadu

Creating an Enabling Environment for DREG

AurovilleConsulting

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EXECUTIVE SUMMARY

In order to meet its ambitious renewable energy targets of 175 GW as well as the longer-term targets as part of its nationally determined contribution (NDC) to the international climate agreement, the role of both distributed renewable energy generation (DREG) and utility-scale renewable energy (RE) are equally important.

Compared to utility-scale RE, DREG is geographically more distributed and hence it has benefits including lesser network capacity issues, improved voltage, lower losses of energy, providing ancillary services and deferring investment for upgrading the grid infrastructure. Further, DREG has a much higher job creation potential. For example, small-scale solar is more labour intensive (24.72 job-year per MW) compared to utility-scale solar (3.45 job-year per MW).

In the solar and wind sectors, for example, the focus has been on ultra-megawatt projects, further accelerated by the introduction of competitive bidding, which has resulted in the drastic fall in the tariffs. While these large projects thrive, an equally conducive policy environment is lacking to promote DREG. In the state of Tamil Nadu, the penetration of DREG has been insignificant. For example, as of January 2019, the total installed rooftop solar capacity stood at 365 MW (refer to Chapter 1). Overall, we estimate that DREG contributes around 11% of the total installed RE capacity in the state.

Promoting the deployment of DREG in the State will require capacity addition planning for DREG, introduction of policy changes, new regulations and standards, and an alternative electricity market design. The key recommendations emerging from this scoping study include:

- mandating DREG-specific targets,
- permitting interconnection of DREG at any node in the existing high tension (HT) and low tension (LT) distribution network,
- determining DREG-specific tariffs that take into account the true cost of generation,
- recognizing the contribution of DREG for overall grid management,
- proactive planning to optimize future addition of DREG, and
- implementing a comprehensive demand response programme.

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1. INTRODUCTION

OBJECTIVES OF THIS PAPER

India, with an average GDP growth rate of 7.51%[1] over the period 2014-18, continues to be a fast growing large economy in the world. With this economic growth, electricity demand will continue to rise. The International Energy Agency estimates that India's electricity demand will increase by a factor of 3 between 2013 and 2040.[2]

In 2017, 76% of India's electricity demand was met by coal.[3] At the Paris Climate conference, in 2016, India has made a commitment to reduce its carbon emission intensity by 33-35% of 2005 levels by 2030. To achieve this goal enabling policy mechanisms, a strong participation of the private sector and a wide-spread and continuous political support across all segments will be required.

Tamil Nadu is a renewable energy (RE) leader among the states in India. As of 2018, 14.3% of all electricity consumed in Tamil Nadu is from renewable sources, primarily wind and solar.[4] Most of the installed RE capacity is at the utility (megawatt and ultra megawatt) scale. Small and medium-scale RE, distributed renewable energy generation (DREG) is in a nascent state. Though the residential rooftop solar sector in Tamil Nadu continues to receive subsidy support, the total installed rooftop solar capacity in January 2019 stood merely at 365 MW.[5] Utility-scale solar accounted for 2,119 MW installed capacity. Given the State's strong focus on utility-scale RE plants, DREG has received, so far, less attention in terms of policy and regulations.

For the purpose of this paper, we focus on grid-connected generation systems, although we are aware that off-grid generators are also distributed in nature. The objectives of this paper are to

- map out the current state of DREG in Tamil Nadu,
- identify challenges and opportunities for small and medium-scale RE generation systems,
- explore the role of DREG in the context of climate change mitigation and energy security, and
- review existing policy and regulations policies in order to identify strengths and gaps in regard to distributed generation.

This paper is being written for policy makers with the objective of providing information that may help creating of an enabling environment for distributed generation.

1 Plecher, H. (2019). Statista. India: Real gross domestic product (GDP) growth rate from 2014 to 2024 (compared to the previous year). Available at: https://www.statista.com/statistics/263617/gross-domestic-product-gdp-growth-rate-in-india/ (accessed on 25 July 2019).

2 International Energy Agency (2015). Indian Energy Outlook. Available at: https://www.iea.org/publications/freepublications/publication/IndiaEnergyOutlook_WEO2015.pdf (accessed on 7 May 2019).

3 Spencer, T., Pachouri, R., Renjith, G. and Vohra, S. (2018). TERI. Coal Transition in India. Available at: https://www.teriin.org/sites/default/files/2018-12/Coal-Transition-in-India.pdf (accessed on 7 May 2019).

4 Bhushan, C.; Bhati, P.; Sreenivasan, P.; Singh, M.; Jhawar, P.; Koshy, S. M.; and Sambyal, S. (2019). The State of Renewable Energy in India. Centre for Science and Environment. New Delhi.

5 Business Standard (2019). India added record 1,836 MW of rooftop solar power in last fiscal: Report India Solar Rooftop Map September 2018. https://www.business-standard.com/article/economy-policy/india-added-record-1-836-mw-of-rooftop-solar-power-in-last-fiscal-report-119070901032_1.html (accessed on 19 September 2019)

THE TRANSITION

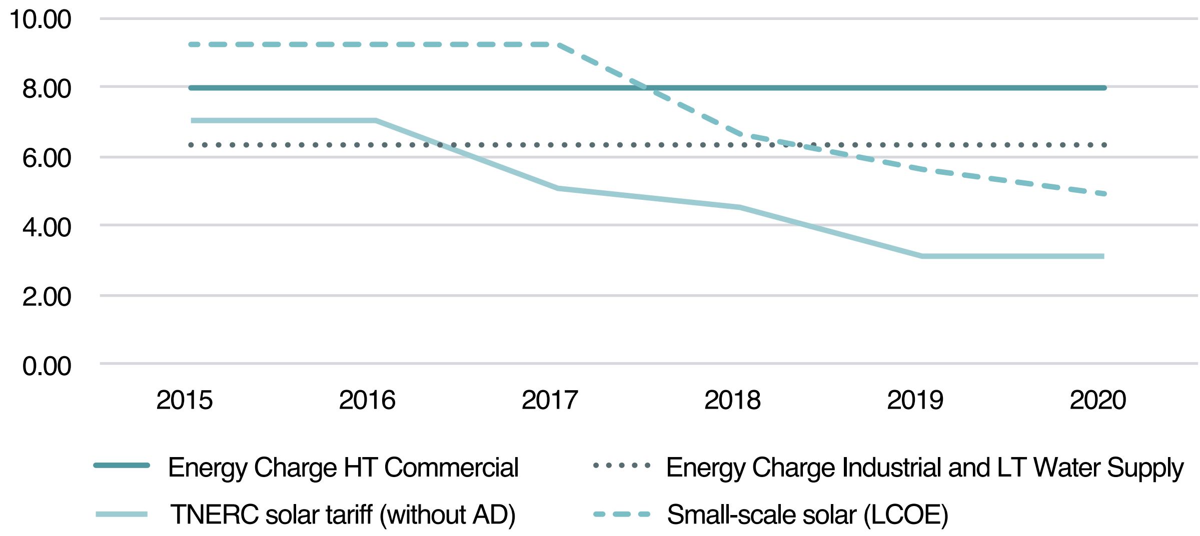
The industrial, twentieth century model of energy management, generation and distribution is essentially based on a centralised model. Large fossil fuel or hydro power plants generate electricity that is transmitted and distributed via a centralised electricity grid. The flow of power is uni-directional; from the power plant to the consumer. With the emergence of new generation and grid management technologies, the electricity sector is witnessing a deep paradigm change. Distributed generation, which is small and medium scale units of generation, mostly renewables, shifts the paradigm from a one-way flow of power to a two-way flow of power. An increasing number of households, communities or organizations generate their own renewable electricity. Distributed generation, in conjunction with demand response, advanced forecasting and storage technologies (taken with DREG, these constitute distributed energy resources or DER), requires grid operators, policy makers and energy professionals to rethink grid operations and the future of the electricity grid itself.

Today, energy-producing consumers (prosumers) are emerging, taking more control of their immediate electricity requirements. In a future dominated by the behind-the-meter model, all buildings with distributed energy resources could permanently operate as independent, self-sufficient units either isolated from or as part of a micro-grid distribution system. This model becomes more and more technically and economically feasible and realistic. Taking the example of Tamil Nadu, the cost of solar energy is already equal to or lower than that of conventional grid power for industrial and commercial consumer segments (Figure 1.1). Grid power cost parity for the domestic consumer segment may be achieved within the next 5 years. With further cost reduction of battery storage solutions, the behind-the-meter model is expected to gain further traction in the near future.

Prosumption

Prosumption means "production by consumers". The term prosumption involves the relationship between production and consumption. In the inter-related process that involves simultaneous production and consumption, individuals become prosumers, in that they consume and produce a product. In the case of electricity this means that the prosumer is producing a portion (or all) of their energy with the surplus being exported to the utility via the grid.

Figure 1.1: Cost of solar vs electricity tariffs for selected consumer categories.



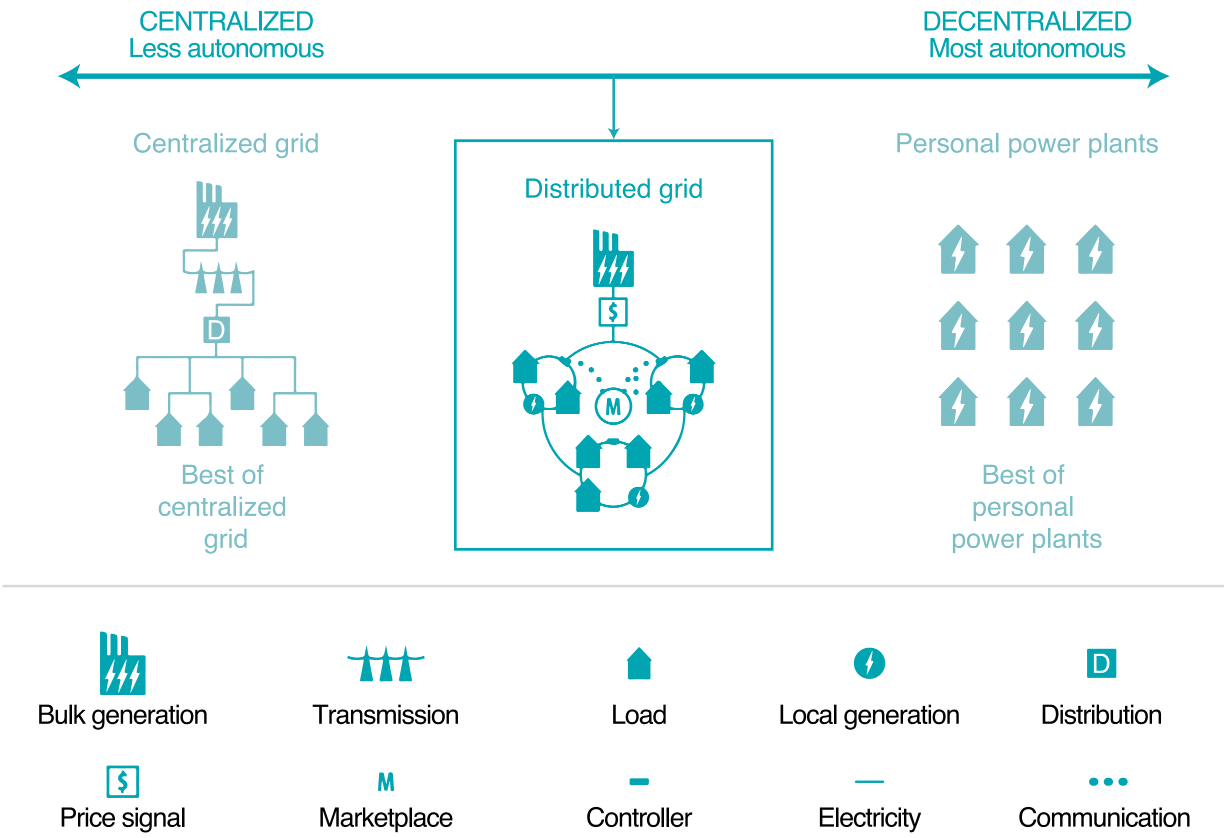
Sources: Data from TNERC tariff orders[6] , MNRE Benchmark costs[7].

Another model, likely to emerge at least for those regions of the world with a strong grid penetration, is a distributed and highly interconnected energy system. For example, consumers equipped with photovoltaic systems still connect to the distribution network, and the grid assumes the role of a balancing system, matching demand and supply. In this model, the basic role of the grid operator in providing a reliable grid network will not change significantly, but grid control and monitoring functions will have to be expanded to the distribution level. The role of the grid operator will be in connecting distributed generation systems, consumer load, distributed storage, demand response programmes and bulk energy supply from centralised generation systems into one grid operation. Such a distributed grid integrates the advantages of the centralised model with the advantages of distributed energy resources and ideally provides cost-effective and renewable electricity supply to meet consumers' needs.

6 Tamil Nadu Electricity Regulatory Commission (TNERC) (2015, 2017, 2018, 2019). Available at: http://www.tnerc.gov.in/Order.htm (accessed on 13 September, 2019).

7 MNRE (2015, 2018, 2019, 2020). Available at: https://mnre.gov.in/file-manager/UserFiles/Scheme-Grid-Connected-Rooftop-&-small-solar-power-plants.pdf, https://solarrooftop.gov.in/notification/Notification-22032017.pdf, https://mnre.gov.in/sites/default/files/webform/notices/Off_Grid-&-Grid-Benchmark-Cost-2018-19.pdf and https://mnre.gov.in/sites/default/files/uploads/benchmark%20cost%202019-20%20%281%29.pdf (accessed on 13 September, 2019).

Figure 1.2: Traditional versus distributed grid.



Adapted from: Transforming the Grid from the Distribution System Out: The potential for dynamic distribution systems to create a new energy marketplace.[8]

The growth trajectory of distributed generation systems in some regions such as Australia, Germany or California is a clear sign of a trend towards a distributed energy system. In Australia, for example residential rooftop solar accounts for 61% of the total installed solar capacity. In Germany, solar systems of a capacity[9] below 100 kW account for a 52.4% of the total installed solar PV capacity[10] and about half of the residential systems installed in Germany during 2017 had on-site energy storage capacity[11]. Recently California made it mandatory to have solar energy systems as part of newly built homes. Every new home under three stories high will need to come equipped with rooftop solar, or source power from a community solar array, starting in 2020

The most significant rise in energy consumption is seen in countries like China, US and India. In many of the developing countries, that will see a

8 Beihoff, B.; Jahns, T.; Lasseter, R.; and Radloff, G. (2014). Transforming the Grid from the Distribution System Out: The potential for dynamic distribution systems to create a new energy marketplace. Available at: https://energy.wisc.edu/sites/default/files/Transforming-the-Grid-from-the-Distribution-System-Out.pdf (accessed on 13 September 2019).

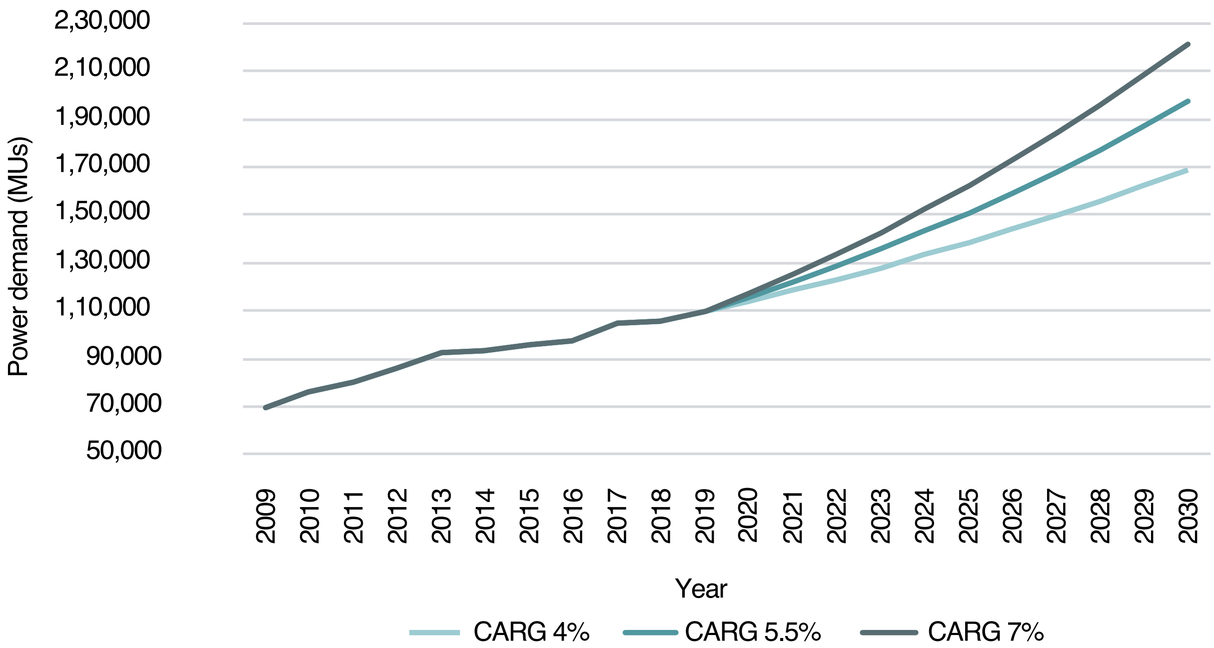
9 PV Magazine (2018). Australia's PV rooftop potential of 43 GW to 61 GW revealed. Available at: https://www.pv-magazine-australia.com/2018/12/11/australias-pv-rooftop-potential-of-43-gw-to-61-gw-revealed/ (accessed on 24 Feb 2019).

10 Lettner, G.; Auer, H.; Fleischhacker, A.; Schwabeneder, D.; Dallinger, B.; Moisl, F.; Roman, E.; Velte, D.; Huidobro, A.; and PVP4Grid. (2018). Existing and Future PV Prosumer Concepts. Available at: https://www.pvp4grid.eu/wp-content/uploads/2018/08/D2.1_Existing-future-prosumer-concepts_PVP4Grid_FV.pdf (accessed on 7 May 2019).

11 REN21 (2018). Renewables 2018 Global Status Report. Available at: http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_-1.pdf (accessed on 7 May 2019).

rise in electricity consumption, DREG may have a strategic role to play to meet the country's, state's or region's energy security and climate targets. The total electricity consumption in Tamil Nadu increased over the last ten years by 83%; from 57,775 MU[12] in 2009-2010 to 1,05,839 MU[13] in 2018. This shows an average annual compound growth of 6.83%. For the year 2030, the electricity consumption for Tamil Nadu is expected to be between 1,68,453 MU (low growth scenario; a compound annual growth rate, CAGR, of 4%) to 2,12,641 MU (aggressive scenario; a CAGR of 7%) (see Figure 1.3). This would be an increase by 54% to 102% over the demand in 2018-19.

Figure 1.3: Past and projected electricity demand for Tamil Nadu.



Source: Data from Power Sector monthly report for January, 2017.[14]

Distributed generation of electricity has the potential to provide suitable solutions for the State to meet its rising energy demand cost effectively and to tackle environmental issues such as emissions and air pollution. The various drivers for advancing distributed renewable generation (DREG) are as follows.

- Competitive cost of renewables for meeting the electricity demand
- Increased energy security and lower dependency on import of fossil fuels
- Meeting renewable energy targets
- Growing of risk of power blackouts due to climate change
- Demand for reliable electricity supply by consumers
- Large-scale roll out of e-vehicles
- Public awareness about air pollution issues
- Optimisation of the use of the electricity infrastructure (benefits distribution companies)

12 Sharma, S. (2016). A Roadmap to Tamil Nadu's Electricity Demand-Supply by 2050. Available at: http://admin.indiaenvironmentportal.org.in/files/file/Tamil%20Nadu%E2%80%99s%20Electricity%20Demand-Supply%202050%20FINAL.pdf (accessed on 11 June 2019).

13 Central Electricity Authority (CEA) (2018). Load Generation Balancing Report 2018-19. Available at: http://www.cea.nic.in/reports/annual/lgbr/lgbr-2018.pdf (accessed on 11 June 2019).

14 CEA (2017). Power Sector Monthly Report – January. Available at: http://www.cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-01.pdf (accessed on 13 September 2019).

India's COP21 commitment

The Paris Agreement, which entered into force in November 2016, requires Parties to put forward their best efforts through "nationally determined contributions" (NDCs). These NDCs represent targets and actions for the post-2020 period. India ratified its' contribution in October 2016. India's first NDC includes commitments:

- to reduce the emissions intensity of its GDP by 33-35% from 2005 levels by 2030.
- to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
- to create an additional carbon-sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.
- to better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.

National Electric Mobility Mission Plan (NEMMP)

NEMMP aims to achieve national fuel security by promoting hybrid and electric vehicles in country. It has set ambitious target of 6-7 million sales of hybrid and electric vehicles year on year from 2020 onwards. Only electric vehicles (EVs) will be sold in India from 2030. The target is that 30% of all operational vehicles are electric.

Air pollution and power generation in India

With at least 550 million Indians, including 50 million children under 5, living in areas where air pollution levels exceed national standards, air pollution is a national health emergency. Exposure to fine particulate matter (PM 2.5) has been linked to mortality from a variety of causes in both adults (ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer) and children (acute lower respiratory infections). India, the second most populous country in the world, has been experiencing extremely high concentrations of fine particulate matter (PM 2.5) in recent decades. In 2015, PM2.5 concentrations in southern, eastern, northern, and western Indian cities were 6.4, 14.8, 13.2, and 9.2 times the World Health Organization (WHO) annual guideline value of 10 μg m–3.[15] In the Global Burden of Disease Study 2016[16], India accounted for 1.034 million of 4.093 million global premature mortalities from ambient PM 2.5 exposure, and ambient PM 2.5 exposure was the second largest risk for health in India. It is estimated that India accounted for 0.65 million out of the 3.3 million deaths resulting from air pollution caused by PM 2.5 globally in 2010.[17]

Impact of climate change on electricity system

Climate change impacts are expected throughout the energy system. On the demand side, the balance of heating and cooling demand is changing because of rising temperatures and changing consumer behaviour patterns. On the supply side, impacts include changes to the averages and variability of wind, solar and hydropower resources; the availability of crops for bioenergy feedstocks; costs and availability of fossil fuels due to melting sea ice and permafrost; the efficiency of PV panels, thermal power plants and transmission lines due to rising temperatures; technology downtime due to changes in the frequency and intensity of extreme weather events.[18]

15 Garaga, R., Sahu, S. K., and Kota, S. H. (2018). A Review of Air Quality Modeling Studies in India: Local and Regional Scale, Current Pollution Reports, 4, 59–73. Available at: https://doi.org/10.1007/s40726-018-0081-0, 2018 (accessed on 20 December 2019).

16 Institute for Health Metrics and Evaluation (IHME) (2018). Findings from the Global Burden of Disease Study 2017.

17 Lelieveld, J.; Evans, J.; Fnais, M.; Giannadaki, D.; and Pozzer, A. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale, Nature, 525, 367–371.

18 Ebinger, J., and Vergara, W. (2011). Climate Impacts on Energy Systems – Key Issues for Energy Sector Adaptation. World Bank study.

2. DEFINING DISTRIBUTED RENEWABLE ENERGY GENERATION

Though there is no universally accepted definition of distributed generation, International Energy Agency (IEA) has defined distributed generation as an on-site generation unit, which works with lower distribution voltage levels.[19] Terminologies such as on-site generation, behind-the-meter generation, embedded generation, dispersed generation etc., are often interchangeablly used. Distributed generation systems are essentially decentralised, modular and more flexible systems, that are located close to the load they serve. For the objective of this scoping paper, we consider only grid-connected generation systems.

Distributed renewable energy generation (DREG), within the scope of this paper, can be defined around the following three parameters:

- the interconnection voltage level
- the integration into existing distribution infrastructure and
- the focus on supplying the generated power to the demand within the distribution network.

High tension (HT) distribution voltage levels in Tamil Nadu range from 11 kV to 110 kV. The Technical Standards for Connectivity of the Distributed Generation Resources by the Central Electricity Authority (CEA) defined distributed generation as generation systems that are interconnected at distribution grid voltage level below 33kV.[20]

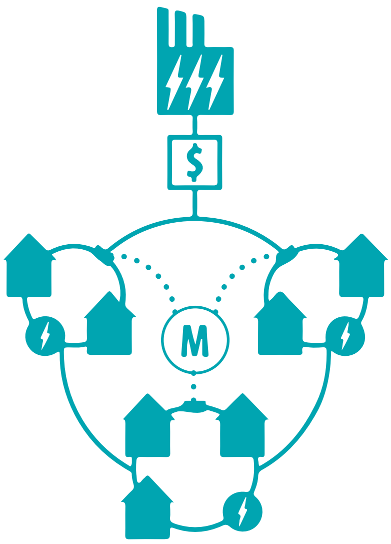
Adopting CEA's definition helps to determine the capacity of distributed generation (either as a single generation unit or as an aggregated capacity) in Tamil Nadu to 9 MW, based on the state's Distribution Code.[21] The actual sizing of distributed generation for respective distribution networks, however, would need to take parameters such as hosting capacity, demand curves and intermittency of generation sources (e.g. solar and wind) into account.

19 Pepermans, G.; Driesen, J.; Haeseldonckx, D.; Belmans, R.; & D'haeseleer, W. (2005). Distributed generation: definition, benefits and issues. Energy Policy. pp. 787-798.

20 CEA (2013). Technical Standards for Connectivity of the Distributed Generation Resources. Available at: http://www.cea.nic.in/reports/regulation/distributed_gen.pdf (accessed on 7 April 2019).

21 TNERC (2018). Distribution Code. Available at: http://www.tnerc.gov.in/regulat.htm#Supply%20code (accessed on 15 November 2019).

Figure 2.1: Defining distributed generation.



1 Grid interface at distribution voltage (in the case of Tamil Nadu: 11 kV, 22 kV)

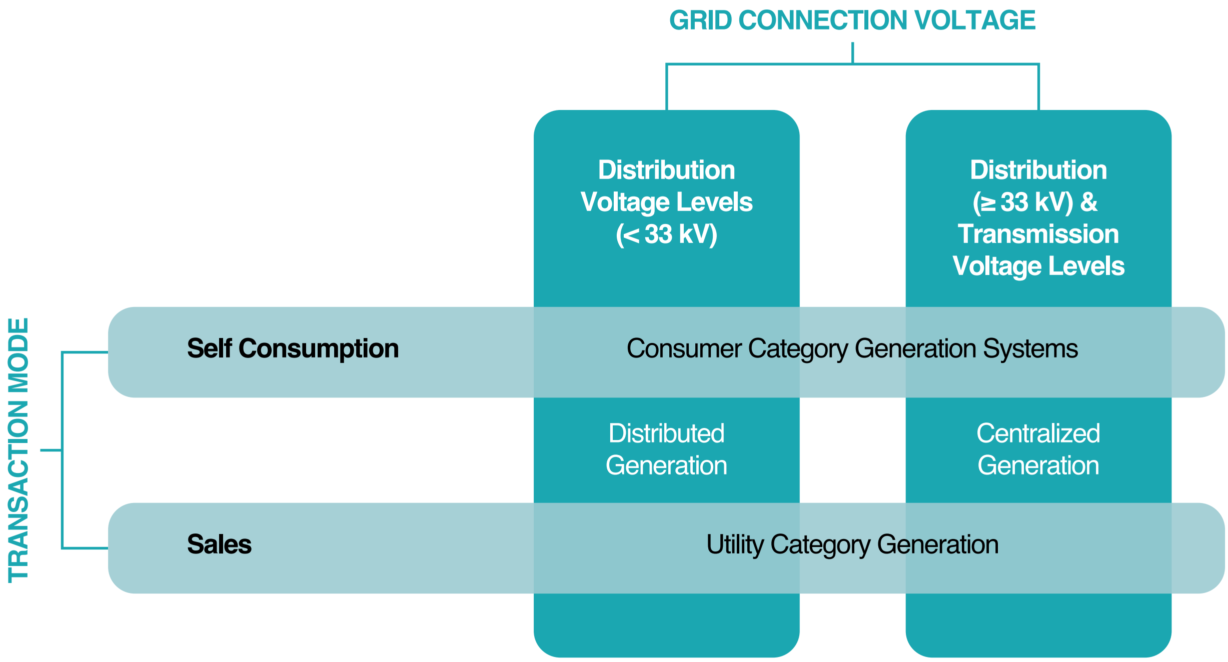
2 Connected to existing LT and HT distribution network (no dedicated evaluation infrastructure)

3 Energy produced from distributed generation primarily for consumption within the distribution network

The primary purpose of defining distributed generation, and in this specific context distributed renewable energy generation (DREG), is to be able to monitor and evaluate past and future growth trajectories for this generation segment and to identify possible opportunities and challenges in terms of regulatory and policy frameworks.

In the Tamil Nadu Solar Energy Policy 2019, a distinction between consumer category and utility category generation systems was introduced. This distinction rests on the mode of transaction between the producer and the consumer, rather than on voltage level of grid connection or the system capacity. The consumer category of solar generation has as its primary purpose as self-consumption of electricity. For the utility category, the primary objective is sale of electricity. However, both categories would fall within the definition of DREG if the grid interconnection voltage is below 33 KV as per the above mentioned definition by CEA.

Figure 2.2: Defining modalities based on transaction mode and voltage.



Notes: Self-consumption at higher distribution (≥ 33 kV) and transmission voltages can occur in case of off-site captive power generation. Further, in this paper, utility category RE generation has often been used to refer to centralised generation. However, strictly speaking, utility category RE can correspond to both centralised or distributed RE generation.

3. DREG TECHNOLOGIES & EXTERNALITIES

This chapter focuses on various RE sources such as solar, wind, hydro and bio energy and their performance characteristics in terms of firmness, footprints (land, CO_2, water), energy return on energy investment and jobs created in the society. These performance characteristics have been defined as follows below:

1.FIRMNESS:

Indicates whether a generation technology can give continuous supply of energy without varying its magnitude. Firmness can be evaluated with respect to different time periods (instantaneously, weekly/ monthly, seasonally).

2.CARBON FOOTPRINTS:

The amount of CO_2 released into the atmosphere during construction and operation phase of the DREG over its entire lifecycle.

3.WATER FOOTPRINTS:

The amount of fresh water utilized during construction and operation phase and fuel supply of the DREG over its entire lifecycle.

4.LAND FOOTPRINTS:

It is the actual land required for a capacity of 1 MW to produce electricity.

5.JOB CREATION:

Jobs created by each resource technology measured in full-time equivalent (FTE). FTE is the ratio of total number of paid hours to total number of working hours in a year. This includes direct (designing, development, management, construction, installation, maintenance etc.) and indirect (manufacturing of equipment and material, supply chain, banking, financial sectors etc.) job creation potential.

6.ENERGY RETURN ON ENERGY INVESTMENT (EROEI):

EROEI is the ratio of the energy produced over the life-time of a generation system to the energy consumed during the manufacturing and operation of the same system. An EROI less than 1 means the energy required for the generation system's manufacturing and operation is more than the energy produced during its lifetime. An EROI higher than 1 means the system has a positive energy return.

Table 3.1 measures the performance characteristics of different DREG technologies on the above performance characteristics.

Table 3.1: Defining performance characteristics of DREG technologies.

Sources	Firmness	Land footprint (acres / MW)	Carbon footprint (Kg CO2e / MWh) [22]	Water footprint (m3 / MWh) [23]	Job Creation (FTE / MW) [24]	EROEI [25]
Solar PV	Low	0 - 9 [26]	18 - 180	0.023 - 1.09	3.4 - 23.19	4
Wind	Medium	0 - 1	7 - 56	0.001 - 0.043	1.21	16
Biomass	High	0.83 - 1.3 [27]	130 - 420	0.13 - 3.32 [28]	16.24 [29]	4
Hydro	High	0.25 [30]	1 - 2200	1.08 - 3060	13.84 [31]	49

22 Schlömer, S.; Bruckner, T.; Fulton, L.; Hertwich, E.; McKinnon, A.; Perczyk, D.; Roy, J.; Schaeffer, R.; Sims, R.; Smith, P.; and Wiser, R. (2014). Annex III: Technology-specific cost and performance parameters. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf (accessed on 25 July 2019).

23 Mekonnen, M. M., Gerbens-Leenes, P. W., and Hoekstra, A. Y. (2015). Environmental Science: Water research and technology. The consumptive water footprint of electricity and heat: A global assessment. Available at: https://waterfootprint.org/media/downloads/Mekonnen-et-al-2015.pdf (accessed on 25 July 2019).

24 Centre for Energy, Environment and Water (CEEW) and National Research Defence Council (NRDC) (2017). Greening India's workforce. Available at: https://www.nrdc.org/sites/default/files/greening-india-workforce.pdf (accessed on 25 July 2019).

25 Tyagi, B. (2017). Green jobs in renewable energy: Sectoral scope and employment structure. Available at: https://mnre.gov.in/file-manager/akshay-urja/october-2017/Images/32-36.pdf (accessed on 25 July 2019).

26 TERI (2017). Addressing land issues for utility scale renewable energy deployment in India. Available at: https://shaktifoundation.in/wp-content/uploads/2018/01/Study-Report-Addressing-Land-Issues-for-Utility-Scale-Renewable-Energy-Deployment-in-India.pdf (accessed on 25 July 2019).

27 Ministry of New & Renewable Energy (MNRE). Frequently asked questions on biomass power generation. Available at: https://mnre.gov.in/file-manager/UserFiles/faq_biomass.htm (accessed on 25 July 2019).

28 World Resources Institute (WRI) & International Renewable Energy Agency (IRENA) (2018). Water use in India's power generation: Impact of renewables and improved cooling technology to 2030. Available at: https://www.irena.org/publications/2018/Jan/Water-Use-in-India-Power-Impact-of-renewables-to-2030 (accessed on 25 July 2019).

29 Kuldeep, N.; Koti, P. N.; Dutt, A.; Bishnoi, T.; and Dalal, A. (2019). Employment Potential in India in Power Sector: A long term assessment of net employment in the conventional and non-conventional sector.

30 National Renewable Energy Laboratory (NREL). (2012) Renewable Electricity Futures Study. Hand, M.M., Baldwin, S., DeMeo, E., Reilly, J.M., Mai, T., Arent, D., Porro, G., Meshek, M. and Sandor, D. eds. 4 vols. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory. Available at: https://www.nrel.gov/docs/fy13osti/52409-ES.pdf (accessed on 25 July 2019).

31 Kuldeep, N.; Koti, P. N.; Dutt, A.; Bishnoi, T.; and Dalal, A. (2019). Employment Potential in India in Power Sector: A long term assessment of net employment in the conventional and non-conventional sector.

Land footprint:

- *Wind: In the case of wind energy, only the actual land footprint required for the wind generator has been considered. The land required for spacing between wind turbines has not been included. For building integrated small wind generators the land footprint is considered at 0 acres/MW.*

- *Solar: Land footprint for crystalline solar PV technology is 4.9 acres/MW, and 9 acres/MW for thin film technology. For rooftop mounted system, the land footprint has been taken as 0 acres/MW*

- *Biomass: For biomass power, the land required for feedstock production has not been factored in*

Carbon footprint:

- *Solar: Carbon footprint ranges from 18-180 Kg CO2e/MWh for utility scale and 26-60 Kg CO2e/MWh for rooftop.*

- *Wind: Carbon footprint ranges from 7-56 Kg CO2e/MWh for on shore and 8-35 Kg CO2e/MWh for offshore.*

- *Biomass: Feedstock, which is considered for biomass life cycle emissions are: switch grasses, miscanthus, willow, eucalyptus, agricultural by-products and forest biomass.*

- *Hydro: The maximum CO2e values include run-off river and reservoir type of hydro-generators.*

Water footprint:

- *System boundaries for the water footprint include water requirements for fuel supply, construction and operation.*

Job creation (FTE):

- *Solar: The job creation potential for small scale solar with 27.32FTE/MW is substantially higher as compared to utility-scale solar with a 6.05 FTE/MW.*

- *Biomass: Data presented is for bio-gasifier plants only. FTE values include jobs created during the construction, operation and maintenance phases; job creation for fuel/feedstock is excluded. The job creation for fuels is estimated at 1.22 FTE/MT.*[32]

- *Hydro: Data presented is for small hydro for a capacity range from 1 MW to 10 MW*

32 Kuldeep, N.; Koti, P. N.; Dutt, A.; Bishnoi, T.; and Dalal, A. (2019). Employment Potential in India in Power Sector: A long term assessment of net employment in the conventional and non-conventional sector.

Firmness: Intermittency is one of the major challenges being faced for the integration of solar and wind generators. Loss of Load Probability (LOLP) and Loss of Expected Energy (LOEE) are two indices to determine firmness of an energy source. LOLP is the value that shows how much time (in the long run) the load on the power system is expected to be greater than the available generation capacity. LOEE is the ratio of expected energy that is not served for a period of time to the total load demand in the same duration of time. Both biomass and hydro power are rated as high on firmness as they are capable of providing constant energy output over time (as long as the supply of feedstock and water supply is constant). Though appropriate wind speeds over the day and sessions may vary considerably, studies comparing LOLP and LOEE of wind and solar energy concluded that wind energy is more firm than solar energy.[33] Thus, wind energy has been rated as medium on firmness. Solar PV is rated as low in terms of firmness, as it provides energy output for limited hours a day (during daytime hours) with considerate variability (e.g. solar production typically peaks at mid-day, there is less production in the morning and evening hours, cloud cover impacts the instantaneous energy output etc.).

As both biomass and hydro power are rated as firm DREG, the utility will benefit from a high capacity addition of these generation technologies, as high firmness contributes to grid stability. They also have a degree of flexibility in terms of active power output (ramping-up and ramping -down of generation). RE technologies can be associated with some lifecycle emission of carbon dioxide and other greenhouse gases (both during construction and operation phases). Among the RE technologies in Table 3.1, wind and solar perform best in terms of CO2 emissions over their lifecycles and thus have the least impact on the climate.

Land footprint: RE technologies take up land for installation and operation this may impact other development goals such as food security and reforestation efforts. The exception is building integrated generation technologies such as rooftop solar and roof-mounted mini wind turbines. Further, land for solar and wind plants can be co-utilised with crop cultivation, which will provide additional source of income for farmers.

Water footprint: Water consumption of DREG, during their construction and operation, is comparatively low when compared to conventional generation technologies such as nuclear (2.2 m^3/MWh) or thermal power (1.6 m^3/MWh) plants, which need large volumes of water for cooling requirements.[34] Tamil Nadu has been declared as a water stressed state[35], thus low water consuming DREG such as solar and wind in particular may be given more deployment priority.

Job creation: Unemployment is one of the major concerns in India.[36] Small-scale solar is the most labour intensive technology among these RE technologies, it can provide 27.32 (including business development and manufacturing sectors in the job creation) full-time equivalent jobs per MW capacity. Studies show wind technology needs the least labour as FTE per MW because of the role of machinery. If employment generation is a key concern of the State, then the promotion of small-scale solar systems should be prioritised.

EROEI: All RE technologies listed above offset their embodied energy during their lifetime. Though hydro is having highest Energy Return on Energy Invested (EROEI), other parameters such as life cycle emission and water consumption make this technology less preferable.

Overall speaking solar and wind perform best on at least 4 out of the 6 selected parameters, their main shortcoming being their lack of firmness. This may be addressed with targeted capacity addition of storage technologies, more firm and flexible DREG generation (e.g. biomass power and hydro) and new power purchase agreements that take benefit of the potential flexibility of wind and solar generation technologies (refer to chapter Enabling Environment).

33 NREL and Power System Operation Corporation (POSOCO) (2017). Greening the grid: Pathways to integrate 175GW renewable energy into India's electric grid. Available at: https://posoco.in/wp-content/uploads/2017/06/National-Study-Executive-Summary.pdf (accessed on 25 July 2019).

34 Mekonnen, M. M., Gerbens-Leenes, P. W., and Hoekstra, A. Y. (2015). The consumptive water footprint of electricity and heat: A global assessment. Available at: https://waterfootprint.org/media/downloads/Mekonnen-et-al-2015.pdf (accessed on 25 July 2019).

35 Gopinath, S. and Kirubagaran, K. (2018). Water crisis in Tamil Nadu and its economic impacts on small holding agriculture. Available at: https://acadpubl.eu/hub/2018-120-5/3/278.pdf (accessed on 25 July 2019).

36 Biswas, S. (2016). Unemployment in India. Available at: https://nationalconference.org.in/up_proc/pdf/23-145352902225-27.pdf (accessed on 25 July 2019).

4. CHALLENGES & OPPORTUNITIES OF DREG

DREG as an emerging, generation paradigm, offers some unique opportunities for achieving a sustainable energy future and for optimizing grid operations. At the same time a number of financial, regulatory, technical and social challenges will need to be addressed in order to fully integrate DREG for a sustainable energy future. Reliability and flexibility of the system has emerged as a major concern for the grid operators as most of the renewable distributed generation (DREG) is highly intermittent (e.g. solar and wind). Operators struggle to guarantee supply and to meet increasing and fluctuating demand, particularly so during peak periods.

We conducted a few expert interviews across all the different DREG technologies (solar energy, wind energy, biomass power), including installers and developers, to assess the current challenges facing DREG. The inputs gathered from these expert interviews along with insights from a desk study are presented below. It needs to be noted that though DREG has its own specific challenges and opportunities, some of them are shared with the RE sector as a whole.

FINANCIAL

⚠ Challenges

- **Requires incentives and subsidies**:
  DREG and energy storage may require additional financial incentives and subsidies to reach market maturity. The current electricity sector has been designed with large power producers in mind. This poses a challenge for DREG to compete in the market. There are currently no subsidies available for small wind and small hydro projects.

- **Non-payment by the utility or backing down:**
  In August 2019, CEA released a report[37] containing state-wise dues by the distribution utilities to RE generators, which stood at more than INR 9,700 cr. Backing down, due to economic reasons (i.e. to go for cheaper power from conventional power plants), of solar and wind plants despite the must-run status of these plants also results in huge losses for RE generators. In case of one of the developers we interviewed, they had to sell off the wind turbines they owned in Tamil Nadu because of the losses they were facing.

- **Preference for big projects:**
  Competitive bidding for solar and wind projects over the last two years have resulted in aggressive bidding and discovery of low tariffs, financially unviable in the long run.[38] This puts smaller enterprises at a disadvantage as only the large players have access to the required financing (including from international investors) in this environment. In the case of the wind sector, where small projects drove the growth of the industry for more than a decade, today it is dominated by large projects (> 25 MW).

  For development of DREG, there is a need to have a DREG-specific feed-in tariffs and capacity targets. In the case of biomass power projects, due to fuel costs and low feed-in tariffs, small projects are not financially feasible (as informed in one of the interviews, this threshold for feasibility is 2 MW) unless it is a co-generation project (such as by a sugar, rice or paper mill).

37 CEA (2019). Report on Payment dues of RE Generators as on 31.07.2019. Available at: http://www.cea.nic.in/reports/others/planning/rti/re_version4.pdf (accessed on 7 November 2019)

38 Vembadi, S., Das, N. and Gambhir, A. (2018). 175 GW Renewables by 2022 – A September, 2018 Update Available at: http://www.prayaspune.org/peg/publications/item/405.html (accessed on 4 September 2019)

Opportunities

- **Deferred investment into grid infrastructure:**
DREG units may defer the investment on expansion of grid infrastructure since consumers start producing and consuming power from DREG which is located nearby. For capacity addition at the utility-scale generation, investments for entire feeder lines have to be made. This immediate lump sum investment can be deferred by the addition of a DREG to an existing feeder network. A case study by CEEW on the Delhi utility BRPL estimates savings from deferral of investment in distribution infrastructure of INR 319/kW of rooftop solar installation.[39] Further, the study estimated a net benefit of INR 5,572/kW after considering other benefits as well costs such as the revenue loss for the utility.

- **Reduced cost of supply during peak hours:**
DREG and energy storage systems can bring relief for the utilities by reducing the power purchase from expensive spot markets, especially during peak demand hours. Storage systems also reduce the economic losses due to blackouts.

- **Financial and technical risks are distributed:**
Utility-scale generation plants are usually owned by single developer/government. When the owner of such systems gets into financial problems, a significant part of the total energy capacity is at risk. In the case of DREG, financial and technical risks are distributed both geographically and in terms of ownership.

39 Neeraj, K.; Ramesh, K.; Tyagi, A.; and Saji, S. (2019). Valuing Grid-connected Rooftop Solar: A Framework to Assess Costs and Benefits to Discoms. Available at: https://www.ceew.in/sites/default/files/Valuing-report.pdf (accessed on 15 November 2019)

POLICY, REGULATORY AND TECHNICAL

Challenges

- **Grid stability issues:**
  There are few technical/operational challenges concerned with DREG units. The electric network was designed to supply from large central power plants. The energy flow in the distribution system was unidirectional. In an active distribution network with DREG, there is bidirectional flow of energy. The excess generation from the DREG can lead to increase in the feeder voltage and can cause instability to the grid

- **Grid connection issues:**
  Obtaining grid connectivity for projects is a major reason for delays and cost overruns

- **No policies for small wind and hybrid systems:**
  Except for consumer category solar (i.e., rooftop solar), there are no specific policies or targets for other small-scale distributed RE systems in the state of Tamil Nadu.

- **Lack of implementation of regulations/guidelines:**
  A major bottleneck for uptake in domestic rooftop solar is procedural delays in energy meter replacement (installation of a bidirectional energy meter for net metering of net feed-in). In the case of Tamil Nadu, for example, there have been long delays in procurement and installation of bidirectional energy meters by the utility. However, the Order on Rooftop Solar Generation passed in March 2019 by Tamil Nadu Electricity Regulatory Commission (TNERC)[40] mandates commissioning within 3 weeks of application for rooftop solar. Further, a provision has been made for consumers to procure the meters from a list of manufacturers put up by the utility.

Opportunities

- **Modular and fast deployment:**
  DREG comprises modular units of small capacity, which can be deployed with a short gestation period.

- **Reduction of T&D losses:**
  DREG is geographically widespread and located close to the load. Hence, well-planned DREG capacity addition can avoid transmission losses entirely and reduce distribution losses significantly. This translates into avoided cost to the utility. The costs for transmission and distribution is up to 18% of the cost of the delivered electricity.[41]

- **Increased system resiliency:**
  The geographical distribution of DREG enhances resiliency of the electricity system.

- **Source for ancillary grid services:**
  DREG can provide active and reactive power on demand. Along with energy storage systems, it can improve the reliability of the power grid by providing additional spinning and ramping reserves.

40 TNERC (2019). Order on Rooftop Solar Generation. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf (accessed on 8 April 2019).

41 TNERC (2018). Order in the matter of R.P.No.4 of 2017. Available at: http://www.tnerc.gov.in/orders/commn%20order/2018/TANGEDCO-RPNo4of2017.pdf (accessed on 25 July 2019).

SOCIAL AND ENVIRONMENTAL

Challenges

- **Lack of awareness:**
  In the state of Tamil Nadu, rooftop solar in the domestic segment has barely taken off. As of the first quarter of 2019, rooftop solar capacity stood at less than 400 MW. One of the reasons for the low installed capacity is the lack of awareness and information for installing rooftop solar systems. Even though national and state policies are in place, more can be done by the Government to make consumers aware of the benefits and share information, such as on subsidies, installers and financing options. Currently, this burden falls on the installers, who have only limited resources.

Opportunities

- **Job Creation:**
  Deployment of DREG creates local job opportunities in business development, designing, manufacturing, transportation, construction and installation. E.g., small scale solar is more labour intensive (24.72 job-year per MW) compared to MW-scale solar (3.45 job-year per MW).[42]

- **Green House Gas emissions (GHG):**
  The direct GHG emissions associated with the RE sources of generation is lower than that of non-renewable sources of energy. The direct emissions are in the range of 350 kg CO_2/MWh to 490 kg CO2/MWh for gas combined cycles and 670 kg CO_2/MWh to 870 kg CO_2/MWh for coal which are non-renewable sources of energy. For renewable sources of energy, except biomass power, direct emissions are zero.[43]

- **Air quality impacts:**
  As of 2019, coal-based power plants contribute to 65% of the total electricity produced in India. Studies show that there are 1.2 million deaths and that there is GDP loss of 3% every year in India because of outdoor air pollution.[44] The cost of pollution-based damage (including health impacts) has been estimated at INR 0.81 per kWh, i.e., if one unit of electricity from renewable source of energy replaces electricity generated from coal then a damage cost of INR 0.81 is avoided.[45]

- **Water security impact:**
  Since DREG is spread out geographically water consumption from a location at a particular point of time is reduced compared to that of utility-scale large power plants. Also, in comparison to thermal and nuclear power plants, technologies such as wind and solar require little water for plant operation.

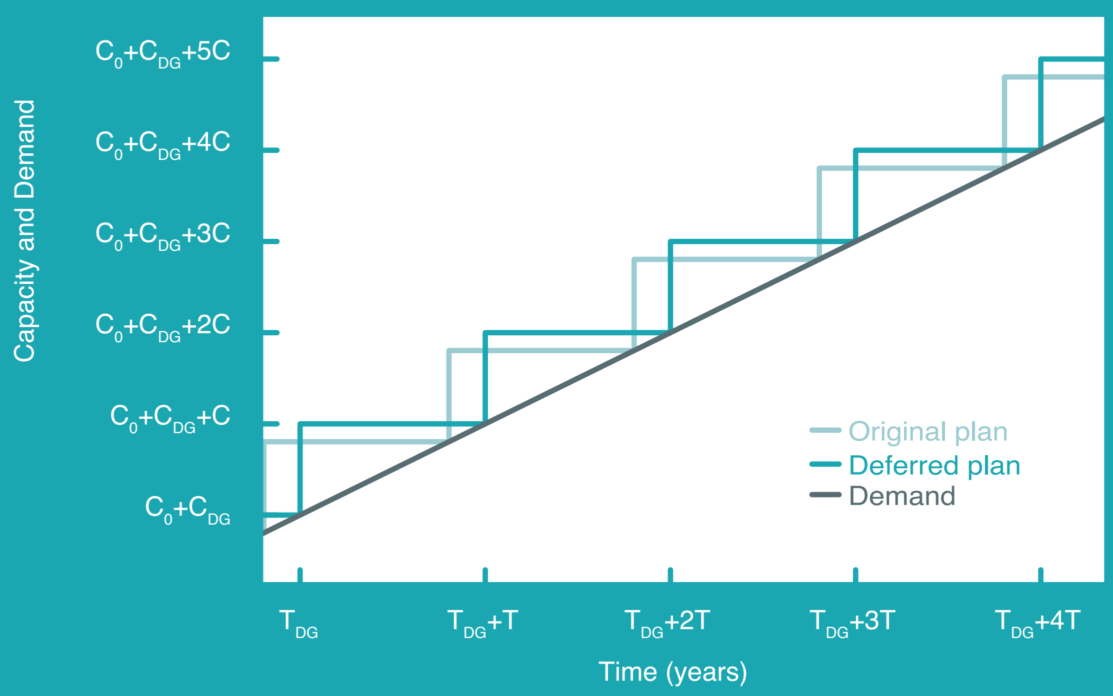
42 Kuldeep, N.; Chawla, K.; Ghosh, A.; Jaiswal, A.; Kaur, N.; Kwatra, S.; and Chouksey, K. (2017). GREENING INDIA'S WORK FORCE: Gearing up for Expansion of Solar and Wind Power in India. Available at: http://www.ceew.in/sites/default/files/CEEW-NRDC-Greening-India-Workforce-report-20Jun17.pdf (accessed on 17 September 2019).

43 Schlömer. S.; Bruckner, T.; Fulton, L.; Hertwich, E.; McKinnon, A.; Perczyk, D.; Roy, J.; Schaeffer, R.; Sims, R.; Smith, P.; and Wiser, R. (2014). Annex III: Technology-specific cost and performance parameters. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf (accessed on 25 July 2019)

44 Greenpeace (2017). Airpocalypse: Assessment of air pollution in Indian cities. Available at: https://secured-static.greenpeace.org/india/Global/india/Airpoclypse--Not-just-Delhi--Air-in-most-Indian-cities-hazardous--Greenpeace-report.pdf (accessed on 25 July 2019).

45 MNRE (2018). Economic rate of return of various renewable energy technologies. Available at: https://mnre.gov.in/file-manager/UserFiles/Draft-Report-Study-on-ERR-for-RETs.pdf. (accessed on 25 July 2019)

Figure 4.1: Deferred investment on account of distributed generation – linear demand growth.



Source: Distributed generation: An alternative to electric utility investments in system capacity.[46]

For grid network expansion and enhancement planning, the initial hosting capacity of a distribution grid capacity is typically oversized in order to account for future increase in electricity demand. Over time the system capacity will be fully utilized, and eventually upgrading of the distribution grid is required.

Introducing DREG to address grid constrains has the potential to defer or avoid investment by the utility into grid capacity enhancements. The figure above illustrates the potential of DREG to defer grid upgradation. The lighter step line represents the original plan and the darker step line represents the deferred plan. Interconnecting a DREG system leads to upstream benefits in the distribution and transmission network. For example, a DREG system interconnected at the LT distribution system, with energy injected largely absorbed by demand within the same LT distribution system, will result in reduced load for both the distribution transformer, the substation and the transmission grid.

46 Hoff, T. E., Wenger, H. J., and Farmer, B.K. (1996). Distributed generation: An alternative to electric utility investments in system capacity. Energy policy, Vol. 24, No. 2, pp. 137-147.

5. STATUS OF DREG IN TAMIL NADU

Introducing DREG-specific indicators at the national and state level is one of the first steps to move the agenda for DREG. As of 2019, there is a clear absence of data on installed capacity or electricity generation from DREG. The only partial exception to this is the rooftop solar sector.

As of September 2018, Tamil Nadu had 312 MW of installed rooftop solar capacity.[47,48] It is about 14% of the total installed grid-connected solar capacity[49] in the state (2,221 MW) or 1.03 % of the total generation capacity[50,51] in the State (30,352 MW). We can assume that the existing capacity of biomass power in the state are connected at voltages below 33 KV and hence can be classified as DREG. With that assumption in mind, DREG accounts for 10.64% of the installed RE capacity or 4.17% of the total installed power capacity in the State.

Tamil Nadu Government plans to develop smart electricity grid infrastructure. One metric for measuring progress of smart grid implementation is the amount of distributed generation capacity (MW) connected to the electric distribution system and available to system operators as despatchable resources.[52,53] Thus, DREG needs to be an essential part of the policy agenda of decision makers in the power sector in the State.

47 Bridge to India (2018). India Solar Rooftop Map September 2018. Available at: https://bridgetoindia.com/backend/wp-content/uploads/2018/12/BRIDGE-TO-INDIA-India-Solar-Rooftop-Map-December-2018-1-1.pdf (accessed on 7 May 2019).

48 We took September 2018 as the reference point for comparison, as it is the latest available data on state-wise installed solar capacity. As of February 2019, the installed rooftop solar capacity stood at 365 MW.

49 Ministry of Statistics and Programme Implementation (2019). Energy Statistics 2019. Available at: http://www.mospi.gov.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf (accessed on 19 September, 2019).

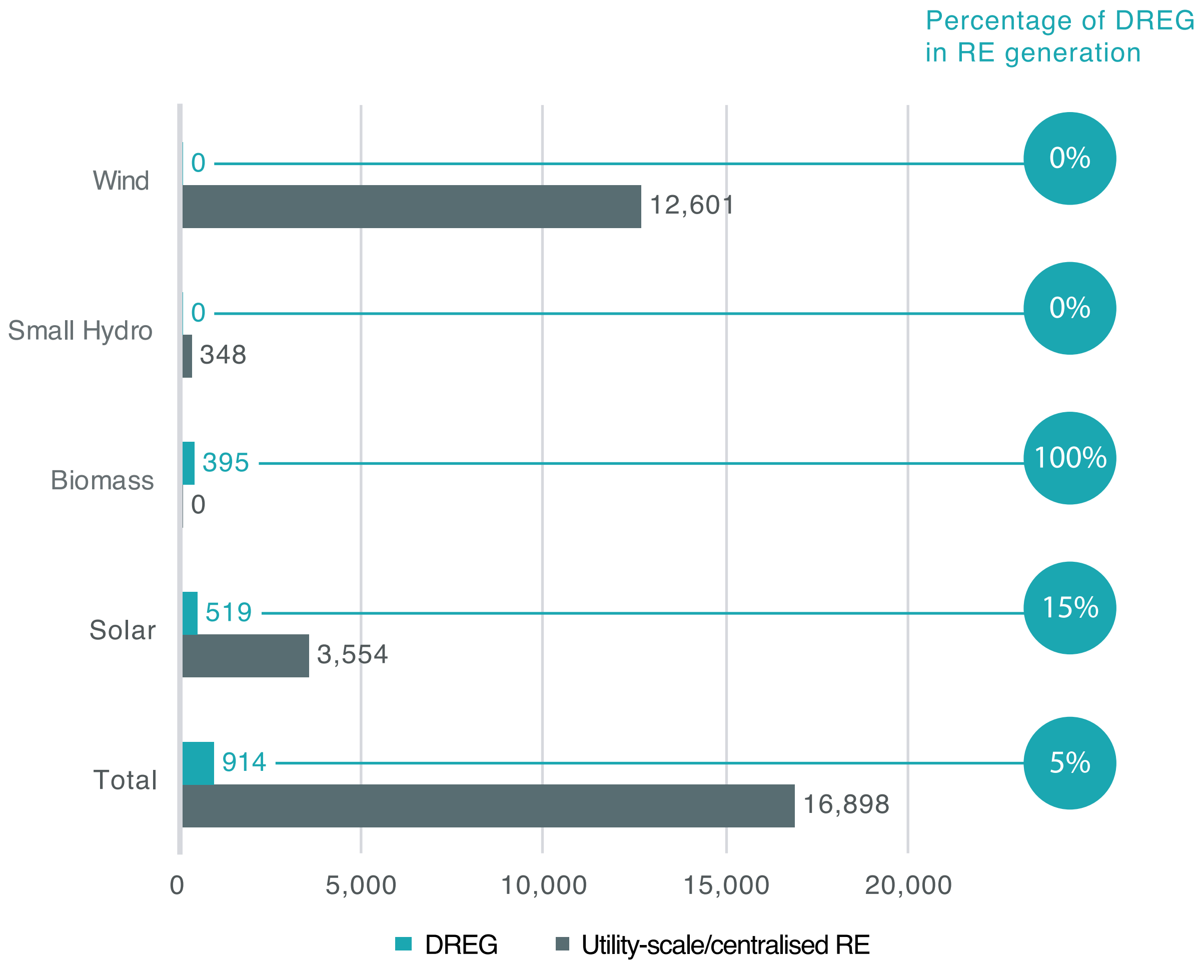
50 This is the generation capacity owned or contracted by the utility, i.e. excludes captive generation and open access.

51 CEA (2019). All India Installed Capacity of Power Stations (as on 30.09.2018). Available at: http://www.cea.nic.in/reports/monthly/installedcapacity/2018/installed_capacity-09.pdf (accessed on 19 September 2019).

52 Accenture (2012). Unlocking the value of metrics. Maximizing smart grid technologies for high performance. Available at:https://www.accenture.com/_acnmedia/accenture/conversion-assets/dotcom/documents/local/fr-fr/pdf_2/accenture-unlocking-value-metrics.pdf (accessed on 13 September 2019)

53 Dupont, B., Meeus, L., and Belmans, R. Measuring the “Smartness” of the Electricity Grid. Available at: https://core.ac.uk/download/pdf/34485325.pdf (accessed on 13 September 2019).

Figure 5.1: Electricity generation (MU) from different RE sources in 2018-19 in Tamil Nadu.

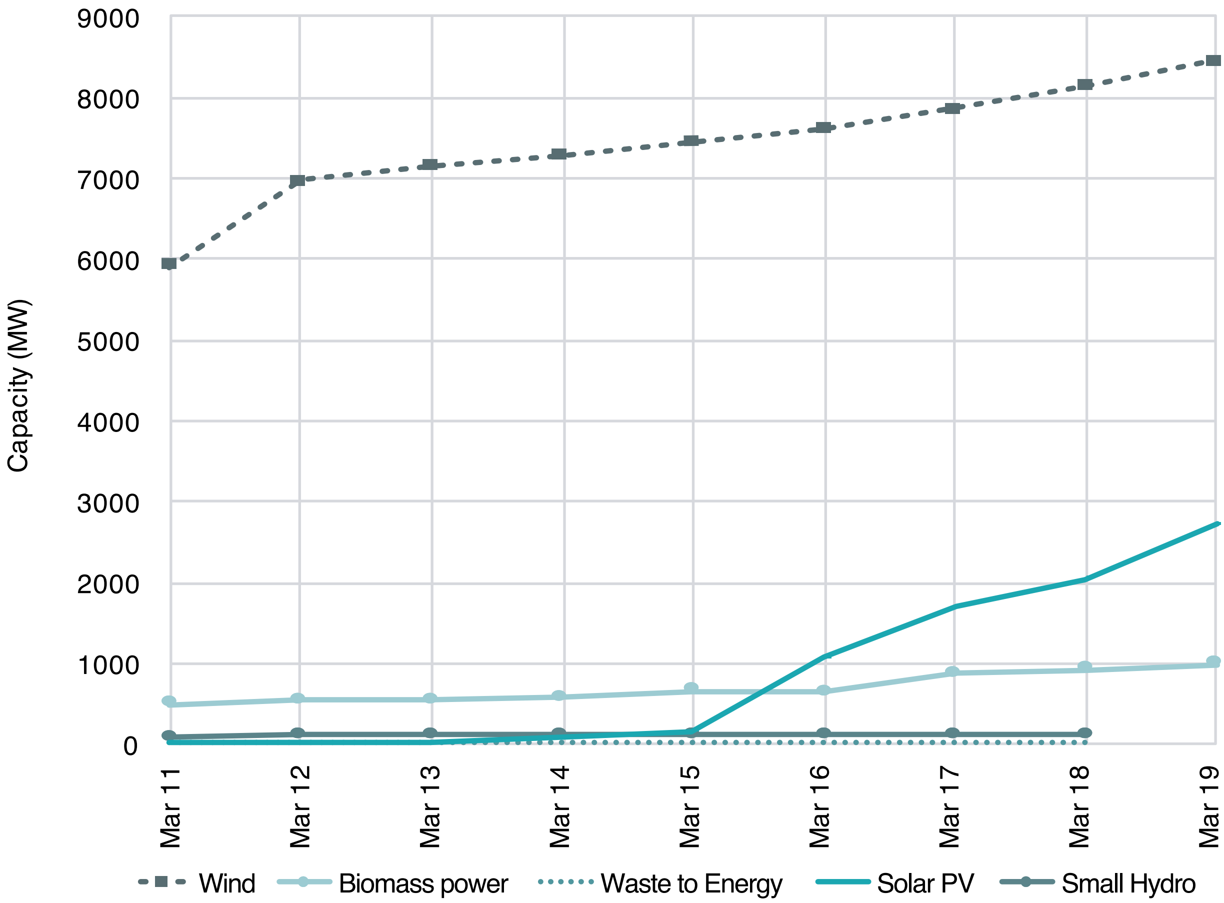


Source: Data from India Stat.[54]

Note: For the purpose of the above graph, all of biomass power capacity has been considered under DREG, while small hydro capacity wasn't similarly categorised. MNRE describes small hydro plants are power plants of sizes below 25 MW. However, data to further disaggregate this capacity as DREG and non-DREG wasn't available.

54 India Stat (2019). Available at: www.indiastat.com (accessed on 24 May 2019).

Figure 5.2: Installed capacity of renewables in Tamil Nadu from 2007 to 2019.



Source: Data from Policy Note of Energy Department, Tamil Nadu[55], and Energy Statistics[56].

The existing gaps in terms of available data on electricity installations and generation in terms of source, ownership and technology (especially for RE sources) will need to be addressed in order to make DREG a policy priority. Access to DREG-specific data helps in determining trends, identifying policies and market design gaps. Therefore, it will be essential for the planning and development of the State's power sector.

55 Policy Note of Energy Department, Tamil Nadu. Available at: http://www.tn.gov.in/documents/dept/7(accessed on 19 September 2019).

56 Ministry of Statistics and Programme Implementation. (2019). Energy Statistics 2019. Available at: http://www.mospi.gov.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf (accessed on 19 September 2019).

6. COST OF DREG

The Levelised Cost of Electricity (LCOE) of a power plant gives the net present value of electricity produced during the economic life of the plant; and is calculated by dividing the total life cycle costs of the power plant (including construction, operation and maintenance, and any fuel costs) by the total energy produced. Compared to utility-scale RE plants, DREG has higher LCOE as it doesn't have the advantage of economies of scale. Setting of realistic tariffs for distributed RE by regulator needs determination of LCOE based on actual market data.

Figure 6.1 plots the levelised cost of energy (LCOE) corresponding to the benchmark costs (see Annexure I for assumptions) for different solar PV system sizes. The figure also plots different electricity consumer category tariffs in Tamil Nadu and the average cost of supply for the distribution utility TANGEDCO. Benchmark costs for grid-connected solar till 500 kW capacity are as issued by Ministry for New and Renewable Energy (MNRE) for the financial year 2019-20[57]; for capacity sizes greater than 1 MW, the capital cost for calculating the LCOE is as per the generic tariff order notified in 2019 for solar power by Tamil Nadu Energy Regulatory Commission (TNERC).[58]

Further, market data[59] on capital cost by system size was obtained from our interviews with installers and developers to arrive at a possible range of LCOE by solar system size.

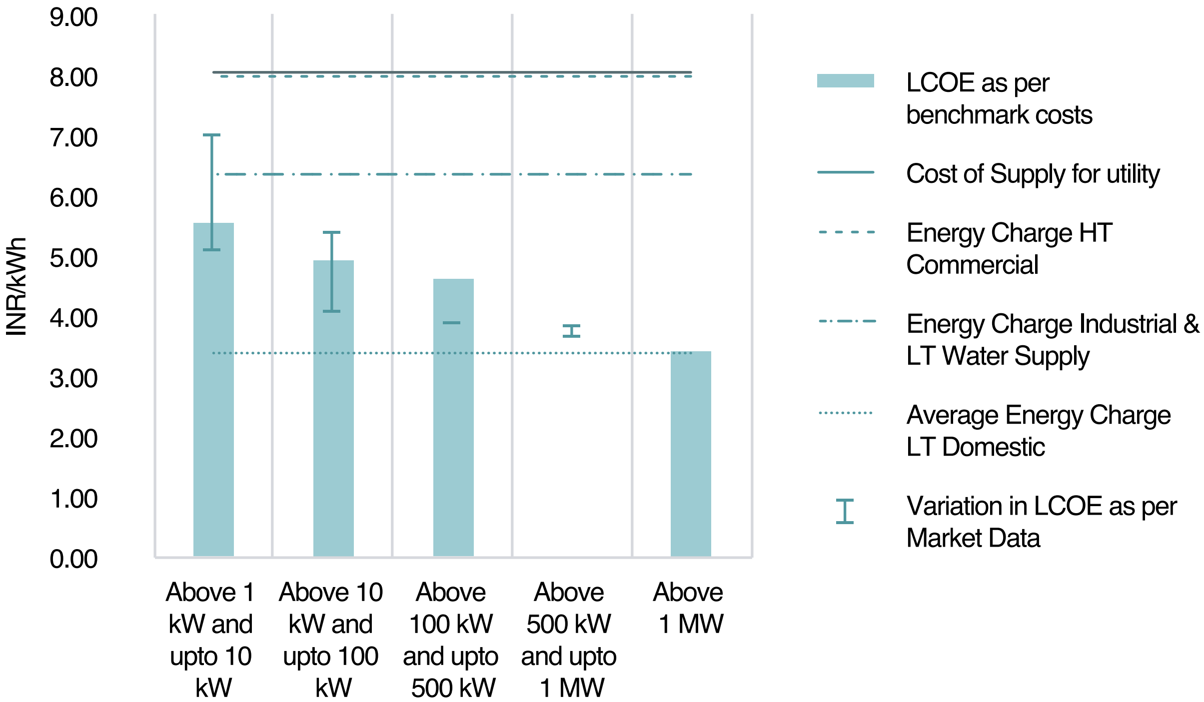
Figure 6.1 illustrates that MNRE's benchmark costs for systems smaller than 10 kW is on the lower side of the market data range. For system sizes between 10 kW and 500 kW, the benchmark costs are more aligned with the market data. A reassessment of benchmark costs for sub-10 kW system sizes by MNRE is required. Further, consumer categories with higher tariffs such as the commercial and industrial categories (tariffs of INR 8.00/kWh and INR 6.35/kWh respectively) can save significantly from solar energy. Since the cost of supply for the utility is higher than these tariffs, it incurs a loss on every unit sold to these consumers. If these categories generate their own power, the utility will be reducing its losses. On the other hand, for the residential consumers, the transition towards solar self-generation does not prove to be financially attractive yet. This is due to the subsidised tariff for residential consumers. Policies that incentivise solar energy installation by domestic consumers would benefit both the consumer and the utility.

57 MNRE (2019). Benchmark costs for Grid-Connected Rooftops Solar Power Plants for the Year 2019-20. Available at: https://mnre.gov.in/sites/default/files/uploads/benchmark%20cost%202019-20%20%281%29.pdf.

58 TNERC (2019). Order on generic tariff for solar power and related issues. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-5-29-03-2019.pdf (accessed on 6 September 2019).45 This is the generation capacity owned or contracted by the utility, i.e. excludes captive generation and open access.

59 The market data gathered consists of 22 data points on the capital cost of the solar system (with only one data point for the 100-500 kW and two for 500-1,000 kW system size categories).

Figure 6.1: Levelised cost of electricity for solar PV.



Notes: The average cost of supply to TANGEDCO per unit of electricity has been taken at INR 8.04/kWh. The energy charges for different electricity consumer categories in the State have been taken from the most recent TNERC tariff and subsidy orders as approved by TNERC for the financial year 2017-18.[60,61] The average energy charge for the domestic segment has been weighted by approved sales for different domestic rate slabs in the recent subsidy order to get the average energy charge per unit, i.e. INR 3.41/kWh.

Figure 6.2 plots the LCOE corresponding to benchmark costs for other technologies along with the tariffs for different consumer categories in Tamil Nadu. In the figure, the market data wasn't plotted to show the real variation in LCOE as enough data points weren't available. The levelised cost calculation (see Annexure I & II for assumptions) in the case of wind, biomass and bagasse is based on benchmark capital and operating costs notified in 2018 by TNERC.[62] For small hydro, the CERC values for the same year have been considered (see Annexure II).[63] HT Commercial and Industrial consumers can save significantly on their electricity expenses by moving to wind power in addition to solar energy. Biomass power has the highest LCOE, close to the cost of supply of power in the State.

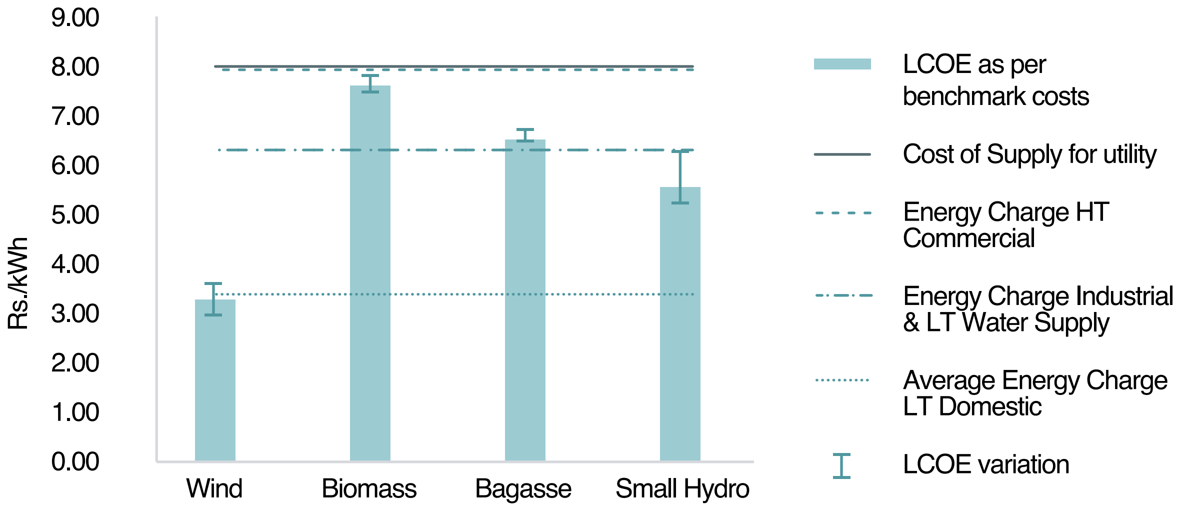
60 TNERC (2017). Determination of Tariff for Generation and Distribution. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2017/TariffOrder/TANGEDCO-11-08-2017.pdf (accessed on 6 September 2019).52 TNERC (2019). Order on generic tariff for solar power and related issues. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-5-29-03-2019.pdf (accessed on 6 September 2019).45 This is the generation capacity owned or contracted by the utility, i.e. excludes captive generation and open access.

61 TNERC (2017). Provision of Tariff subsidy for FY2016-17 by the Government of Tamil Nadu. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2016/SUBSIDY%20ORDER%202016-17.pdf (accessed on 6 September 2019).

62 TNERC (2019). Tariff orders of the Commission. Accessed at: http://www.tnerc.gov.in/Order.htm.

63 CERC (2018). Determination of levelised generic tariff for FY 2018-19 under Regulation 8 of the Central Electricity Regulatory Commission (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2017. Available at: http://www.cercind.gov.in/2018/orders/2.pdf (accessed on 6 September 2019).

Figure 6.2: Levelised cost of electricity for other RE technologies.



In our market survey, in the case of biomass power, three data points for systems smaller than 5 kW indicated an LCOE range of INR 9.77-10.28/kWh. In the case of small hydro, the available data ranged from INR 5.37/kWh for a 1 MW system to INR 22.53/kWh for a 1 kW system. Data available for wind systems with sizes less than 10 kW showed an LCOE range of INR 4.66-6.56/kWh. In the case of wind and biomass power, the market data suggests the actual costs are considerably higher than the benchmark costs shown in the figure.

With energy storage expected to become financially viable in the near future, it will facilitate higher penetration of DREG. In Tamil Nadu, no pilot project with grid-connected energy storage has been implemented as of November 2019. The Tamil Nadu Solar Energy Policy 2019 encourages determination of time-of-day solar energy feed-in tariffs, which has not been implemented till date. Further, conducive market and policy instruments to accelerate cost reduction of storage technologies are required.

It is to be noted that Figures 6.1 and 6.2 only represent the cost of generation. If the power is being wheeled for remote consumption, additional open access charges will apply. These charges include transmission and wheeling charges (INR 0.12/kWh and INR 0.21/kWh respectively), transmission and wheeling losses (applicable in kind), and cross subsidy surcharge (INR 1.67/kWh for HT Industry and INR 1.98/kWh for HT Commercial).[64] In the case of solar and wind power, 50% of the wheeling and transmission charges applicable to conventional power will be levied (as per latest orders on tariffs for solar and wind power by TNERC). Further, for open-access solar power, 70% of the cross subsidy surcharge for conventional power will be levied, whereas it is 60% for other RE sources.[65,66,67] Put together, these charges will increase the cost of procuring RE by more than INR 2.00 every unit.

As was noted in the previous chapter, solar and wind sectors currently only favour (ultra) megawatt projects at very low tariffs, which are unviable for DREG. To make DREG viable, system capacity-specific feed-in tariffs are necessary. The capital cost (and other parameters like rate of interest, CUF) assumed for DREG should be closer to market reality, and the tariffs should reflect higher market costs for the smaller DREG systems. Currently, in Tamil Nadu, net feed-in tariff for rooftop solar is even lower than the feed-in tariffs for utility category solar systems and covers less than 50% of the LCOE of rooftop solar. Lastly, location-specific tariffs can optimize the addition of DREG to the distribution network (see corresponding section in Chapter 7).

64 TNERC (2017). Determination of Tariff for Generation and Distribution. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2017/TariffOrder/TANGEDCO-11-08-2017.pdf (accessed on 6 September 2019).

65 TNERC (2019). Order on generic tariff for Solar power and related issues. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-5-29-03-2019.pdf (accessed on 23 September 2019).

66 TNERC (2018). Order on generic tariff for Wind power and related issues. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2018/Wind-6of2018.pdf (accessed on 23 September 2019).

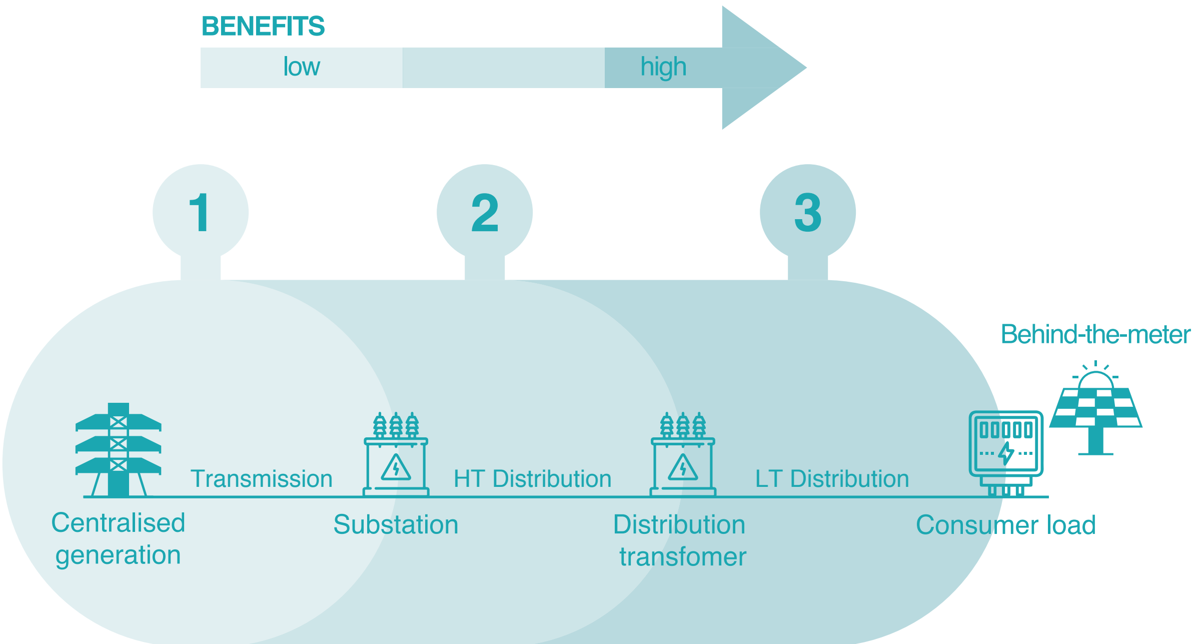
67 TNERC (2018). Comprehensive Tariff Order for Biomass based Power Plants. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2018/BiomassT.O.3of2018.pdf (accessed on 23 September 2019).

7. ENABLING ENVIRONMENT

DREG, if well planned, has substantial potential for creating upstream benefits in the network for the utilities such as avoiding grid congestion, deferring and avoiding investment in transmission and distribution infrastructure, reducing T&D losses and avoiding investment into additional generation capacity addition by the utilities. The benefits of reduction in T&D losses and infrastructure costs depend on the location of the DREG in the system. Therefore, it can be argued that, the closer the DREG is to the load, the better it is for the overall system. For example, a behind-the-meter DREG may lead to avoided system costs upstream from the metering point. DREG connected anywhere in the LT or HT distribution network may lead to avoided system costs upstream from that interconnection point (refer to Figure 7.1). Considering these potential advantages of DREG, some of the questions to be asked are: How can grid operators leverage the benefits of DREG? What policies and regulations are required to support integration of DREG? What market design options are available to ensure that benefits of DREG integration are shared between the generators, utilities and the prosumers?

Creating an enabling environment for DREG, that offers a win-win situation for all stakeholders, utility, consumers and generators, will need a new set of instruments. It requires adapting policies, regulations and standards. It also requires new market design and planning instruments. Figure 7.2 lists some instruments that can be utilized for creating an ecosystem in which DREG can grow. References to Tamil Nadu's electricity sector and to international case studies are provided.

Figure 7.1: Upstream benefits of DREG to distribution/transmission utility.



	1	2	3
Benefits	• Third biggest potential impact on reducing distribution and transmission losses • Load reduction on transmission network • Potential to defer and avoid infrastructure upgradation on the transmission side	• Second biggest potential impact on reducing distribution and transmission losses • Load reduction on transmission and HT distribution • Potential to defer and avoid infrastructure upgradation on the HT distribution and transmission side	• Biggest potential impact on reducing distribution and transmission losses • Load reduction on transmission, HT and LT distribution network • Potential to defer and avoid infrastructure upgradation along the entire network
Challenges	• Ensure maximum consumption from DREG within HT distribution network	• Ensure maximum consumption from DREG within LT network	• Limited control of DISCOM on capacity addition; reduction in energy sales
Opportunities	• Proactive planning for DREG addition based on substation-specific load curves and hosting capacity • Introduce location, time and technology-specific DREG tariffs • Strategic deployment of storage capacity at substation level • Active demand side management programs; incentivise active and reactive power balancing	• Proactive planning for DREG addition based on distribution transformer-specific load curves and hosting capacity • Introduce location, time and technology-specific DREG tariffs • Strategic deployment of storage capacity at distribution transformer level • Active demand side management programs; incentivise active and reactive power balancing	• Remote active and reactive energy export control • Provide credit lines to consumers or RESCOs for setting up DREG • Consumer tariff rationalization • Introduce location, time and technology-specific DREG tariffs

Figure 7.2: Instruments for an enabling environment for DREG.

POLICY AND REGULATIONS

- DREG targets and Mandates
- Technical standards, protocols and regulatory framework
- Mandates and regulations for demand response
- DREG-specific tariff regulations

MARKET DESIGN

- Active and reactive power balancing market for DREG
- Market mechanisms for demand response
- DREG-specific tariff design
- Innovative financing mechanisms for behind-the-meter DREG

PLANNING

- Identify best interconnection locations for DREG
- Plan DREG addition to reduce network costs and constraints
- Advanced forcasting for DREG integration

DREG MANDATES AND TARGETS

Mandates and targets are powerful tools to drive capacity addition and to stimulate enabling regulations and the overall DREG market. Often Governments determine a minimum share of capacity or share of generation of electricity from renewables or DREG for the electricity sector. The Government sets a target and lets the market or the regulator determine the price. This target or mandate can be placed on the producers, distributors or consumers.

Tamil Nadu

The Tamil Nadu Solar Energy Policy 2019 has a target for consumer segment (behind-the-meter) solar energy capacity of 3,600 MW. No other DREG specific targets or mandates exist for Tamil Nadu.

Case Study: Solar Energy Targets, India

India has set an ambition solar energy target of 100 GW for the year 2020. 40% of the overall target is allocated to rooftop solar.

INTERCONNECTION VOLTAGES, PROCEDURES AND STANDARDS

Interconnection standards are meant to ensure safety, reliability and service quality of the electricity network. Standards cover technical requirements, specifications and application procedures to make interconnection reliable. Clear, forward-thinking rules are essential to maintain the safety and reliability of the grid, while also enabling the adoption of DREG. Standards will need to be reviewed and updated on a regular basis to address emerging issues and to incorporate new technologies.

Tamil Nadu

Interconnection standards and processes for the consumer segment of solar generators (behind-the-meter) are well defined. The capacity limit for behind the meter consumer segment solar generators is set at 100% of the contracted demand of the consumer and is further limited in capacity of up to 4 kW solar for a 240-Volt single phase connection at up to 112 kW at a 415 Volt three phase connection. In addition, the total installed consumer segment solar capacity is limited at 90% of the distribution transformers capacity.[68] An online application streamlines the application process and the application fee of INR 100 is moderate.

The Tamil Nadu Solar Energy Policy 2019 permits interconnection of utility category solar generators, with the primary purpose of selling solar energy, at any voltage level. Regulations to enable the same are yet to be put into practice in the State. The current practice, however, is that generators availing gross feed-in of solar energy require to be at least 1 MW generation capacity. TANGEDCO does not provide for interconnection to existing distribution networks but requires the generators to pay for a dedicated evacuation feeder and related equipment.[69]

DREG, other than the solar consumer category with net feed-in mechanism, are treated at par with bigger generation systems, when it comes to interconnection standards, processes and charges. Interconnection charges for solar generators in Tamil Nadu are currently (as of November 2019) at INR 16,300/MW per year. For the consumer category of solar, with the primary purpose of self- or behind-the-meter consumption, HT consumers, agriculture and huts are currently excluded from the net feed-in mechanism. The exclusion of HT consumers prevents educational institutions, commercial and industrial entities and other entities such as municipalities with a HT service connection from installing rooftop solar.

The Central Electricity Authority of India developed well-defined technical standards and processes for connectivity of the distributed generation, including storage capacity. Unlike other countries, no further differentiation based on capacity size in terms of interconnection process is being made in India. The licensee is required to conduct an interconnection study to determine:

- the point of inter-connection, required interconnection facilities and modifications of the existing electricity system, if any, to accommodate the interconnection;
- the maximum net capacity of the distributed generation resource at a particular location for single-phase and three phase generators connected to a shared single or three phase system respectively, based on the capacity and configuration of the electricity system, and imbalance in the power flows that distributed generation resource may cause;

68 TNERC (2019). Order on Rooftop Solar Generation. Available at: http://tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf (accessed on 7 April 2019).

69 TANGEDCO. Grid Connectivity Agreement for Solar Power Plants with Distribution Licensee Network with interface voltage 33 KV and below. Available at: https://www.tangedco.gov.in/linkpdf/5%20Grid%20Connectivity%20Agreement%20.pdf (accessed on 8 April 2019).

- likely impact, if any, on the quality of service to consumers connected to the electricity system and measures to mitigate the same; and
- additional measures to ensure safety of the equipment and personnel.[70]

Case Study: The Small Generator and Interconnection Procedure, USA

The Small Generator and Interconnection Procedure (SGIP) by the US Federal Energy Regulatory Commission (FERC) is a three tiers review system for interconnection requests for all eligible technologies and systems up to 20 MW, including those interconnecting to both the distribution grid and the transmission grid.

The three tiers are:
- Level 1: Small generating facilities no larger than 500 kW
- Level 2: Certified facilities no larger than 2 MW that do not qualify for the Level 1 process
- Level 3: Facilities no larger than 20 MW not qualifying for the Level 1 or Level 2 process

Fees for interconnection requests increase with each Level. A Level 1 request must submit $100 fee; a Level 2 request must submit $500 fee; and a Level 3 requests must submit a deposit of $1000 or 50% of the estimated cost of the feasibility study (whichever is less). The process for each level differs as well; in general Level 1 requests require an evaluation and no additional studies. Level 2 requests require an initial review and possibly a supplemental review and/or modifications to either the small generating facility or the utility facilities. Level 3 requests may include a scoping meeting (which may be waived), a feasibility study (which may be waived), system impact study, and facilities study. Level 2 and 3 both require a signed Small Generator Interconnection Agreement before the systems may begin operation. The forms for requests and agreements are standard SCC determined forms.[71]

Case Study: ConEdison, New York

ConEdison a local electric utility in New York, USA allows PV systems of less than 200 kW to connect to networks without requiring a comprehensive engineering review.

70 Ministry of Power (2013). Technical Standards for Connectivity of the Distributed Generation Resources. Available at: http://www.cea.nic.in/reports/regulation/distributed_gen.pdf (accessed on 7 April 2019).

71 Federal Energy Regulatory Commission (FERC) (2016). Standard Interconnection Agreements & Procedures for Small Generators. Available at: https://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp (accessed on 7 April 2019).

ADVANCED STANDARDS FOR GRID INVERTERS

Advanced inverters have the capability to provide essential grid management services such as: voltage control, reactive power control, riding-through of voltage and frequency disturbances, and soft start after power outages. To enable use of these functionalities grid codes and equipment standards will need to be updated and market mechanisms will need to be designed to compensate for these ancillary services. For an active and real time control, standardization of communication and operational procedures between DREG operators and utilities will be required. Data of advanced inverter-enabled DREG, of a certain capacity, should be visible to the utility in order to optimize grid operations.

Tamil Nadu

The TNERC order on Generic Rooftop Solar Generation 2019[72] stipulates the following requirement for Solar inverters:

- Automated isolation – anti islanding protection
- Manual isolating disconnect switch
- Restrict the harmonic generation, flicker within the limit specified in the relevant regulations issued by the Central Electricity Authority
- Sine wave inverter suitable for synchronizing with the distribution licensee's grid

Case Study: IEEE 1547-2018 standard

The IEEE 1547-2018 standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. The criteria and requirements are applicable to all DER technologies interconnected to EPSs at typical primary and/or secondary distribution voltages.

The IEEE 1547-2018 standard sets the following functional requirements for DREG inverters:

- shall be capable of actively regulating voltage,
- shall ride through abnormal voltage/frequency,
- shall be capable of frequency response,
- may provide inertial response, and
- mandatory communication interface.[73]

In Germany, all solar systems larger than 30 kW are required to be controllable by the grid operator.[74]

72 TNERC (2019). Order on Rooftop Solar Generation. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf (accessed on 8 April 2019).

73 Institute of Electrical and Electronics Engineers (IEEE) (2018). IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. Available at: https://standards.ieee.org/standard/1547-2018.html (accessed on 7 April 2019).

74 NREL (2015). Methods for Procuring Power System Flexibility. Greening the Grid. Available at: https://www.nrel.gov/docs/fy15osti/63040.pdf (accessed on 9 April 2019).

ANCILLARY SERVICES

Advanced inverters and storage provide ancillary grid network services such as frequency ancillary services (balancing of the system), and non-frequency ancillary services (voltage control and black-start capability). Market mechanisms and standards for DREG will need to be developed to enable the use of these services.

(i) Reactive power balancing (voltage control):
Reactive power balancing and voltage control in distribution grids is attracting increasing attention from the distribution grid operators as DREG deployment increases. Although voltage issues are largely local network issue, it could, if not managed, cascade to the wider electricity network. Reactive power requirements vary depending on system conditions, e.g. more reactive absorption may be needed to mitigate over-voltage and more reactive injection will be used to prevent voltage reductions. Compared to large-scale transmission-connected generators, DREG is more distributed across the grid network and thus may provide reactive power support more efficiently as it is closer to the part of the system that needs support.

(ii) Active power balancing (frequency balancing):
Active management of DREG includes the capabilities to limit or ramp up generation for short periods in order to address frequency and load balancing issues. This requires the use of communications equipment, communication standards and centralised control systems. How this flexibility is procured is strongly shaped by the regulatory context. Utilities use contractual mechanisms or market design mechanisms to extract flexibility from generators.[75] DREG provides flexibility to the power grid by reducing its output or by increasing its output. This can occur autonomously under some programmable regime, or when directly controlled by the grid operator, or by an aggregator. For distributed solar power, this typically happens through advanced inverter control.

Tamil Nadu

Tamil Nadu Grid Code mandates that generation stations shall generate and absorb reactive power as per instructions of the State Load Dispatch Centre. No payments however are made to generating companies for such services.[76] Curtailment of renewables for active power control, without financial compensation, is a common practice. It is estimated that at total of 4.3% wind and solar generation is being curtailed per year.[77] Despite numerous directives by the regulator (TNERC), the state utility tends to shut off such renewable power if they fear overloading the grid. Curtailment also occurs because of commercial motives. The earlier PPAs signed by TANGEDCO with solar developers were at high tariffs; as solar energy prices have declined drastically since then, some of these plants face regular curtailment. Various mechanisms to check curtailment such as introduction of forecasting and scheduling, thermal flexing, penalties on the utility, and compensation to developers through multi-part tariff structure, among others currently remain at draft/discussion stage.

Case Study. Xcel Energy, Colorado

Xcel Energy's Model Wind Power Purchase Agreement (PPA) provides an example of a mechanism that enables the system operator to collect forecasting data from wind power generators. Sections of the Model Wind PPA includes protocols for automatic generation control for wind generators and

75 NREL (2015). Methods for Procuring Power System Flexibility. Greening the Grid. Available at: https://www.nrel.gov/docs/fy15osti/63040.pdf (accessed on 9 April 2019).

76 NREL (2005). Tamil Nadu Electricity Grid Code Notification No. TNERC/GC/13/1 Dated 19.10.2005. Available at: http://www.tnerc.gov.in/regulation/TNEGC.pdf (accessed on 19 April 2019).

77 NREL. Greening the Grid – Tamil Nadu. Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric. Available at: https://www.nrel.gov/docs/fy18osti/70953.pdf (accessed on 14 April 2019).

provisions related to compensation for wind generators when Xcel Energy curtails wind output.[78]

Case Study: Flexible Ramping Product, California

California, has introduced the concept of "Flexible Ramping Product". This product is designed to enhance reliability and market performance by procuring flexible ramping capacity in the real-time market (in 5 and in 15-minutes intervals). The flexible ramping product is designed to ensure a margin of sufficient ramping capacity beyond the forecasted ramping needs to protect against power balance violations. In this 5 and 15-minute interval market during ramping periods, the grid operator pays generators at the market price per kWh to remain off, so that they are available to turn on during a subsequent 5-minute interval if ramping needs exceed forecasts. The market is also open to solar, wind, and storage resources.[79, 80]

Case Study: Flexibility Bonus, Germany

In 2012 Germany introduced a 'flexibility bonuses' within the German Renewable Energy Act. It remunerates the installation of additional capacity able to provide more flexible modes of operation. Instead of designing and optimizing the plant for continuous generation, the flexibility bonus incentivizes generators to experiment with different operation modes. Biomass power plant operators, for example, use gas reservoirs, variable feeding of the fermenters to increase flexibility.[81]

Case Study: Energinet Denmark

The Danish system operator Energinet has introduced limitations in the allowed exchange of reactive power between the transmission and the distribution grids. Distribution grid operators are required to maximize reactive power compensation within the distribution network. Reactive power sources and sinks are placed at strategic points within a distribution grid. DREG serves as an aggregated reactive power compensator providing voltage control and saving investments in other reactive power compensators.[82]

Case Study: Power Potential Project, UK

The Power Potential project proposes the creation of a Reactive Power market using DREG in the South East Region of the UK as the transmission network has reached its capacity (limited by dynamic voltage stability and thermal capacity). The Power Potential project aims at alleviating these network constrains by procuring reactive and active power services from DREG, using a market based mechanism, required to maximize reactive power compensation within the distribution network. Reactive power sources and sinks are placed at strategic points within a distribution grid. DREG serves as an aggregated reactive power compensator providing voltage control and saving investments in other reactive power compensators.[83]

78 Greening the Grid. New Resources – Xcel Model Wind and Solar PPA, Model Semi-Dispatchable PPA and Semi-Dispatchable RFP. Available at: https://greeningthegrid.org/news/new-resource-xcel-model-wind-and-solar-power-purchase-agreement (accessed on 17 April 2019).

79 Martinot, E. (2016). Grid Integration of Renewable Energy: Flexibility, Innovation, Experience. Available at: http://martinot.info/Martinot_AR2016_grid_integration_prepub.pdf (accessed on 9 April 2019).

80 California ISO (2018). Flexible Ramping Product Uncertainty Calculation and Implementation Issues. Available at: https://www.caiso.com/Documents/FlexibleRampingProductUncertaintyCalculationImplementationIssues.pdf

81 MWM (2016). Use the Flexibility Bonus – Flexible Biogas Future with MWM. Available at: https://www.mwm.net/files/upload/mwm/issuu/referenz_flexpraemie_ahe_EN.pdf (accessed on 20 April 2019).

82 Anaya, K. L. and Pollitt, M. G. (2018). Reactive Power Procurement: Lessons from Three Leading Countries. Cambridge Working Papers in Economics: 1854. Available at: http://www.econ.cam.ac.uk/research-files/repec/cam/pdf/cwpe1854.pdf (accessed on 9 April 2019).

83 Sanz, I. M.; Stojkovska, B.; Wilks, A.; Horne, J.; Ahmadi, A. R.; and Ustinova. T. Enhancing transmission and distribution system coordination and control in Great Britain using power services from distributed energy resources. Available at: https://www.nationalgrideso.com/document/127511/download (accessed on 9 April 2019).

DEMAND RESPONSE (DR)

Demand response (DR) is most suited to loads that can be time-shifted without serious consequence, such as cooling and heating, water pumping, and some industrial processes.

There are three types of demand response:

- shiftable loads
- sheddable loads, and
- additional loads (refer to active power balancing in this chapter).

DR resources are increasingly becoming recognised as a cost effective way to achieve reliable peak demand reductions.

Tamil Nadu

Other than the crude DR practice of load shedding, DR in Tamil Nadu is in a nascent state. In 2003 a Demand Side Management cell was formed at TANGEDCO. In 2013 Demand Side Regulations were notified by TNERC, these regulations focus primarily on energy conservation and efficiency and do not address opportunities of DR mechanisms for the State's electricity sector.[84]

Case Study: Florida Power & Light (FP&L)

Florida Power & Light (FP&L) maintains large direct load control programs for all customers. It provides incentives for residential customers to allow the utility to temporarily shut off or modify the operations of electric water heaters, air conditioners, space heaters, and pool pumps during system emergencies. Commercial customers can enrol air conditioners in a similar program.

The utility installs direct load controllers on equipment to enable shutting-off or modifying operations, which are incentivised on a dollars-per-kW basis. FP&L estimates their demand response program has a capacity of about 2,000 MW.[85]

Case Study: Hawaiian Electric Company (HECO)

With regulatory approval, Hawaiian Electric Company (HECO) developed a rate schedule rider allowing participants to reduce load when requested in exchange for a reduction in demand charges. Compensation was $5 to $10 per kW-month of nominated load and $0.50 per kWh during the load-shedding event.The pricing was intended to match utility resources. However, in practice, the compensation level was not cost effective, as it was determined to be more expensive than dispatching the highest cost existing generation.[86]

84 TNERC (2013). Tamil Nadu Electricity Regulatory Commission (Demand Side Management) Regulations, 2013. Available at: http://www.tnerc.gov.in/regulation/DSM/DSM-20-1-26-02-2013-English.pdf (accessed on 14 April 2019).

85 Florida Power & Light (2016). Ten Year Power Plant Site Plan 2016-2025. Available at: https://www.fpl.com/company/pdf/10-yearsite-plan.pdf (accessed on 14 April 2019).

86 Gagne, D.; Settle, E.; Aznar, A; and Bracho, R. (2018). Demand Response Compensation Methodologies: Case Studies for Mexico. Technical Report NREL/TP-7A40-71431 Available at: https://www.nrel.gov/docs/fy18osti/71431.pdf (accessed on 11 April 2019).

TIME-OF-DAY TARIFFS

Static (determined in advance) or dynamic (determined in real time based on actual system conditions) time-of-day tariffs (ToD) on the consumer side help in shifting electricity demand towards time periods when generation is abundant and consequently reducing consumption for time periods with generation constraints. Static or dynamic ToD tariffs for generators can incentivize a diversity of DREG generation technologies, storage solutions and demand side management initiatives.

Tamil Nadu

ToD tariffs for the HT industrial consumers have been introduced. Industries are billed at 20% extra on the energy charges for the energy recorded during peak hours and get a rebate of 5% on energy charges during off-peak hours. Peak hours are defined as 6:00 am-9.00 am and 6.00 pm-9:00 pm. Off peak hours are fixed as 10:00 pm-5:00 am. ToD tariffs for other consumer categories have not yet been introduced.[87]

The Tamil Nadu Solar Energy Policy 2019 suggests the introduction of ToD solar energy feed-in tariffs in order to encourage solar energy producers and solar energy storage operators to feed energy into the grid when energy demand is high.[88] As of April 2019, ToD tariffs have not been determined.

Case Study: Time-of-day solar feed-in tariff, Victoria

EnergyAustralia, a retailer, is offering customers in Victoria a solar feed-in tariff, which changes according to the time of the day. Victorian customers who have a solar power system receive higher tariff for feeding energy back to the grid at times of peak demand, such as the late afternoon to early evening. The top feed-in tariff in the TOD scheme is AUD 0.29/kWh and applies during 3:00 pm-9:00 pm. The tariff drops to AUD 0.103/kWh during shoulder periods. This includes 7:00 am-3:00 pm and 9:00 pm-10:00 pm on weekdays. It also applies during 7:00 am-10:00 pm on weekends. Off peak times offer the lowest rate. Customers feeding in overnight during 10:00 pm-7:00 am will receive AUD 0.071/kWh. Owners of solar battery systems can choose to store excess energy and feed it back to the grid when it's most needed.[89]

87 TNERC (2017). Determination of Tariff for Generation and Distribution. Order in T.P. No.1 of 2017 dated 11-08-2017. Available at: http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2017/TariffOrder/TANGEDCO-11-08-2017.pdf (accessed on 17 April 2019).

88 Energy Department, Government of Tamil Nadu (2019). Solar Energy Policy 2019. Available at: http://teda.in/wp-content/uploads/2019/02/SOLARPOLICY2019.pdf (accessed on 7th April 2019).

89 Energy Australia. Feed-in Tariffs. Available at: https://www.energyaustralia.com.au/home/solar-and-batteries/solar-power/feed-in-tariffs (accessed on 7 April 2019).

LOCATION-SPECIFIC TARIFFS

Levelised cost of energy (LCOE) typically forms the basis of determining tariffs for DREG. This tariff determination approach does not account of the location impact of the DREG. Location-specific tariffs or incentives for DREG can attract DREG capacity addition to strategic points of the distribution network thereby optimizing overall system performance. This can address network capacity issues, improve voltage, improve efficiency and defer or avoid investment for upgrading the grid infrastructure.

Tamil Nadu

Location specific tariffs for DREGs are currently not being discussed in Tamil Nadu

Case Study: Locational System Relief Value (LSRV), New York

The prime example of such a location-specific incentive is being explored in New York with a Locational System Relief Value (LSRV). LSRV provides compensation based on the project's ability to inject energy during the top ten peak hours within areas that have an impending system need. The project's energy injections during the local top ten peak hours is multiplied by a fixed $/kW-year.

Case Study: Value of Solar (VOS), Austin, Texas

VOS is a measure of system attributes such as transmission costs, generation costs, environmental externalities, and other inputs. It accounts for the negative or positive impact of distributed solar energy on each of these attributes. VOS is an effort to associate a quantifiable benefit with each kWh of distributed solar fed into the grid. That number becomes the kWh rate at which solar distributed generation would be compensated. VOS represents a departure from net metering. Austin Energy's VOS rate is based on a "buy-all, sell-all" approach where the distributed generation customer buys all of the electricity it consumes from the distribution utility at one rate, and then separately sells all of its distributed generation output to the utility at the VOS rate.[90]

90 Zummo, P. (2015). Rate Design for Distributed Generation: Net Metering Alternatives. Available at: https://www.publicpower.org/system/files/documents/ppf_rate_design_for_dg.pdf (accessed on 25 July 2019).

TECHNOLOGY-SPECIFIC TARIFFS

Tariff regulations can encourage a diversity of generation technologies provided that the tariffs vary according to technology type. Technology-specific feed-in tariffs are a simple instrument that steer the achievement of policy objectives such as innovation, climate protection, RE targets, employment generation and regional development. Such a tariff setting approach has the potential of creating a market for all DREG, especially so for technologies that are in the early development to market competitiveness.

Tamil Nadu

Technology-specific tariffs are a well-established practice in Tamil Nadu. The regulatory commission sets tariffs for solar, wind, hydro, municipal solid waste based power generation, biomass and bagasse based co-generation plants.

Case Study: The Office of Gas and Electricity Markets (Ofgem), UK

Ofgem an independent National Regulatory Authority has set technology and capacity specific feed-in tariffs for various RE technologies. The feed-in tariff for wind has been determined as per details below:

Table 7.2: Feed-in tariff for wind energy.

Capacity (kW)	Feed-in tariff (pence/kWh)
0 - 50	8.24
50 - 100	4.87
100 - 1500	1.55
1500 - 50000	0.47

Source: Ofgem Website[91]

91 Ofgem (2019). Available at: https://www.ofgem.gov.uk (accessed on 19 April 2019).

CAPACITY-SPECIFIC TARIFFS

Capacity-specific tariffs account for the variable capital cost in relation to capacity (MW). The lowest payment level is typically offered to the largest plants, reflecting the gains that result from economies of scale. Differentiating tariff setting by project size is an appropriate tool to determine tariffs that reflect actual project costs and helps to capture the benefits of both large- and small-scale deployment by enabling deployment to occur at both scales. In the absence of capacity-range specific tariffs there could be windfall profits for large projects and leave insufficient returns for smaller projects. This could lead to preventing small capacity systems from entering the market.

Tamil Nadu

Tamil Nadu has only limited experience with differential tariffs based on installed capacity. In March 2019, TNERC announced the policy for rooftop solar, which set a net feed-in tariff at 75% of either the pooled cost of power or at 75% of the last utility-scale solar feed-in tariff or at 75% of the tariff discovered in latest solar bidding – whichever is less. This results in a tariff for rooftop solar which is much lower than the cost of generation and the tariff for large-scale solar. The approach taken by the regulator goes against international trends of setting higher differential tariff for small-scale generators. For small hydro projects with a capacity of more than 5 MW but not exceeding 25 MW capacities, the regulator decides the tariff on case-to-case basis.[92]

Case Study: Size-differentiated Feed-in Tariff, Germany

Germany offers size-differentiated feed-in tariff for biogas, biomass, hydro power, solar, and geothermal. For example, solar systems of up to 100 kW receive a fixed 25 years FIT. Systems between 100 and 750 kW get a feed-in premium, and a tendering scheme for systems between 750 kW and 10 MW has been put in place. The maximum PV system size is generally 10 MW. Utility-scale solar is not promoted in Germany.[93]

92 TNERC (2005). Tamil Nadu Electricity Grid Code Notification No. TNERC/GC/13/1 Dated 19.10.2005. Available at: http://www.tnerc.gov.in/regulation/TNEGC.pdf (accessed on 19 April 2019).

93 Solar Power Europe (2018). Global Market Outlook for Solar Power / 2018 – 2022. Available at: http://www.solarpowereurope.org/wp-content/uploads/2018/09/Global-Market-Outlook-2018-2022.pdf (accessed on 20 April 2019).

SMART GRID — ADVANCE MONITORING AND CONTROL SYSTEMS

Today, electrical grids are being augmented with new digital tools, enabling more efficient operation in the midst of the distributed energy transformation. The pairing of emerging digital technologies with DREG and the conventional tools delivers greater ability to integrate higher levels of RE resources and better utilization of existing infrastructure. Smart grid standards are required before commencing a smart grid development.

Standards will ensure that
(i) devices have the capabilities that utilities require
(ii) smart devices are interoperable
(iii) that equipment manufactures receive guidance.

Case Study: Ujwal Discom Assurance Yojana (UDAY) in Tamil Nadu

Under UDAY, a scheme of the Central Government for financial and operational turnaround of electricity distribution companies TANGEDCO committed to the following targets.[94]

- Achieving 100% Distribution Transformer (DT) Metering by 30th June, 2018
- Achieving 100% feeder metering by 30th June, 2017
- Installation of Smart Meters for all consumers (other than agricultural consumers) consuming above 500 units/month by 31st December, 2018 and consumers consuming above 200 units/month by 31st December, 2019

As of April 2019, 100% of urban and 95% of rural feeders are being metered. 76% of urban feeder and 0% of rural feeder metering has been implemented. Metering on the distribution transformer level of the LT distribution network has not yet commenced but is under planning.[95] Smart metering for all consumers is in a nascent stage and has not been rolled out yet.

A pilot for smart metering is being planned in Chennai. TANGEDCO, through Chennai Smart City Limited, intends to a smart grid pilot project in Chennai. The pilot includes Smart Meters with AMI (Automated Metering Infrastructure), conversion of all streetlights to LED, rooftop solar for all Government Buildings and biogas generators.[96]

Case Study: Tata Power Delhi Distribution, Delhi

Tata Power Delhi Distribution has implemented an Advanced Distribution Management Solution (ADMS), which will facilitate advanced monitoring, analysis and improve control and planning operations, enabling the utility to enhance the reliability, safety, and efficiency of Delhi's distribution network. ADMS is an integrated system that captures the network data and acts as a single source of information. It integrates SCADA, OMS (Outage Management System) and DMS (Distribution Management System) on a single platform.[97]

94 Ministry of Power, Government of India (2017). Tripartite Memorandum Of Understanding Amongst Ministry of Power, Government of India AND Government of Tamil Nadu AND Tamil Nadu Generation and Distribution Corporation Limited for achieving turnaround of Tamil Nadu Generation and Distribution Corporation Limited. Available at: https://powermin.nic.in/sites/default/files/uploads/MoU_Tamilnadu.pdf (accessed on 12 April 2019).

95 Ministry of Power, Government of India (2019). Ujawal Discom Assurance Yojana (UDAY). Available at: https://uday.gov.in/state.php?id=21 (accessed on 25 July 2019).

96 Chennai Smart City Limited (2019). Available at: https://cscl.co.in/focus-areas/smart-energy (accessed on 12th April 2019).

97 Tata Power DDL (2019). Company Profile. Available at: https://www.tatapower-ddl.com/corporate/our-company/company-profile (accessed on 17 April 2019).

Case Study: IEEE's Smart Grid Standards

IEEE has more than 100 standards in development relevant to smart grids.

IEEE's standardization work in smart grids includes the following.[92]

- Smart grid interoperability that defines data flows for reliable, secure, bi-directional flow of electric power, and identifies the necessary communication infrastructure
- Networking and Communications addressing broadband/narrowband over powerline
- Cyber security for smart grid addressing cyber security for Intelligent Electronic Devices
- Smart metering and demand response for communication protocols, smart energy profiles and for smart metering functionality
- Substation automation including time protocol, synchronization work, and electric power system communication
- Electric vehicle charging: which specifies the design interface of electric vehicles and direct current and bi-directional chargers that utilize battery electric vehicles as power storage devices

98 IEEE. Smart Grid Standards. Available at: https://smartgrid.ieee.org/resources/standards (accessed on 11 April 2019).

ADVANCE METERING INFRASTRUCTURE

Advance metering infrastructure (AMI) including remote, real-time reading capabilities is being introduced in many countries. Advanced meters enhance the opportunities in developing demand response programs and in providing network flexibility.

Customer facing functionalities of most AMI include the following.[99]

- Remote, real-time reading
- Registering time-of-day consumption and production
- Registering time interval consumption
- Real-time read capability
- Communication ability
- Ability of the meter to communicate with devices in the home

Grid-facing meter capabilities include the following.

- Remote service connection and disconnection switching
- Power quality reading
- Outage identification and restoration notification
- Generation of distribution system-level data for planning purposes

Tamil Nadu

Under the Chennai Smart City project domestic consumers and other consumer categories of consumers in Greater Chennai will be provided 'smart meters.'

Case Study: New Delhi Municipal Council, New Delhi

New Delhi Municipal Council (NDMC) is planning to replace 75,000 conventional electricity meters with smart meters. The smart meters are part of the overall advanced metering infrastructure solutions (AMI), which uses a GPRS technology for communication between the meters and distribution utilities. It is expected that this will reduce aggregate technical and commercial (AT&C) losses and increases billing efficiency.[100]

Case Study: Smart Meter Mandate, UK

In 2008, the UK Government announced its intention to mandate energy suppliers to install smart meters for their customers. To make smart meters interoperable between energy suppliers, the Government proposed to set new minimum standards. In 2013, the Department of Energy & Climate Change imposed a legal obligation on energy suppliers to install smart meters in all homes and small businesses by 2020.

The Department aims to use the smart metering program to:

- put in place the technology needed within the home to enable smarter energy systems;
- provide the information on consumption and cost that consumers need to engage better with their energy use, so that they can reduce consumption, bills and carbon emissions;

99 Linvill, C.; Sedano, R.; Brutkoski, D.; Binz, R.; and Bracho, R. (2018). First Steps in the Smart Grid Framework: An Optimal and Feasible Pathway Toward Power System Reform in Mexico. Subcontract Report NREL/SR-6A50-68464. Available at: https://www.nrel.gov/docs/fy18osti/68464.pdf (accessed on 13 April 2019).

100 Economic Times of India (2018). EESL partners with NDMC to replace 75,000 electricity meters with smart meters in Delhi. Available at: https://economictimes.indiatimes.com/industry/miscellaneous/eesl-partners-with-ndmc-to-replace-75000-electricity-meters-with-smart-meters/articleshow/63748642.cms (accessed on 12 April 2019).

- avoid the costs of manual meter reading and complaints about billing, and improve customer service by energy suppliers; and
- increase competition between energy suppliers by helping consumers to become better informed and engaged.

Following a competitive tendering process, the Government awarded a license to build and operate the Data and Communications Company (DCC) infrastructure. The Smart Meters and DCC infrastructure are interdependent and developing them has required the Government to coordinate energy suppliers, meter manufacturers, DCC and others. While the DCC infrastructure has been in development, energy suppliers have commissioned their own separate communications infrastructures.[101]

101 National Audit Office (2018). Rolling out smart meters. Report by the Comptroller and Auditor General. Available at: https://www.nao.org.uk/wp-content/uploads/2018/11/Rolling-out-smart-meters.pdf (accessed on 12 April 2019).

ADVANCED FORECASTING FOR DREG

Accurate prediction of DREG generation is essential for the balance of power supply and demand and helps reduce some of the uncertainty associated with the variability of DREG generation. Being a cost-effective tool at the hands of the grid operators, accurate forecasts help reduce the amount of operating reserves needed for the system. The better and more frequent the opportunities to use forecasts, the more impact that forecasts will have on systems operations. Wind and solar forecasts are critical for reducing the uncertainty associated with variable RE generation. Updating forecasts on a sub-hourly basis greatly increases the benefit of these forecasts, so long as the electricity system allows for corrective actions to be made within these timeslots.

Tamil Nadu

Tamil Nadu introduced mandatory generation forecasting for all wind and solar energy generators (excluding rooftop solar) connected to the intra-state transmission or distribution system, including those connected through pooling sub-stations, and using the power generated for self-consumption, or sale within or outside the State. Forecasting is done by wind and solar generators connected to the state grid, or by Qualified Coordinating Agency (QCA) on their behalf. The forecast is generator centric. Forecasts are provided to the State Load Despatch Centre on a day-ahead and a week-ahead basis in 15-minutes time blocks.[102]

Case Study: Germany

The transmission system operators in Germany use forecasts for trading purposes and for grid information analysis. Forecasts are calculated on a regional level and aggregated for a Germany wide forecast. Forecasts of solar and wind production are also for trading and for load flow calculations at the level of grid nodes (e.g. substations, distribution transformers). To keep track of the load in the grid an accurate and detailed forecast of solar and wind production is essential to ensure grid stability. Therefore, wind and solar power forecasts are done at the level of grid nodes to provide information about the expected amount of wind and solar power coming from lower grid levels. By accumulating the forecasts of all transformer stations of the distribution grid transformer station, forecasts for the transmission grid can be generated. Load flow calculations are then used to prevent congestions by pro-active measures. The transmission system operator can inform the distribution system operator about the required amount of power that has to be curtailed at a certain transformer station as well as the time period of curtailment.[103]

102 TNERC (2017). Forecasting, Scheduling and Deviation Settlement for Solar and Wind Generation Regulations, 2017. Available at: http://www.tnerc.gov.in/regulation/draft%20regulations/2017/Draft%20FandS%20Regulations-28-12-2017.pdf (accessed on 11 May 2019).

103 GIZ (2015). Technology. Variable Renewable Energy Forecasting – Integration into Electricity Grids and Markets – A Best Practice Guide. Available at: https://energypedia.info/images/2/2a/Discussion_Series_06_Technology_web.pdf (accessed on 12 May 2019).

AGGREGATION OF DREG

An aggregator is an entity that groups multiple agents in a power system to act as a single entity when engaging in power system markets or selling services to the operator. Operating many DREG or DERs (storage, demand response etc.) together creates a sizeable capacity similar to that of a conventional generator. An aggregator can help in better integration of RE resources by providing both demand- and supply-side flexibility services to the grid. Demand-side flexibility is provided by aggregating demand-response resources or energy storage units to act as per grid requirements.[104]

Tamil Nadu

Aggregation does currently not exist in Tamil Nadu.

Case Study: Netherlands

Founded in 2016, Eneco CrowdNett is a Dutch-based aggregator of home batteries and provides grid services through a network of behind-the-meter batteries owned by prosumers. Prosumers are provided batteries at a discount and receive an additional payment in exchange for access to 30 % of the battery capacity at any time during the day.[105]

104 International Renewable Energy Agency (IRENA) (2019). Aggregators – Innovation Brief. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Landscape_Aggregators_2019.pdf?la=en&hash=388A36E4EB2723D2324C4B08329055F3121FD534 (accessed on 12 May 2019).

105 IRENA (2019). Aggregators – Innovation Brief. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Landscape_Aggregators_2019.pdf?la=en&hash=388A36E4EB2723D2324C4B08329055F3121FD534 (accessed on 12 May 2019).

PROACTIVE PLANNING OF DREG CAPACITY ADDITION

Although detailed studies may be required for determining the impact of DREG on the distribution system, a hosting capacity analysis can serve as a good starting point. A hosting capacity analysis indicates the maximum amount of DREG that specific locations on the distribution grid can safely accommodate without requiring major infrastructure upgrades. At a DREG penetration below a circuit's hosting capacity no significant negative impact will be expected.

Tamil Nadu

The Tamil Nadu Grid code includes a dedicated section on system planning. It specifies the policy and procedures to be applied in planning of Tamil Nadu state grid. The code formulates the responsibilities of the State Transmission Utility (STU) for generation planning but limits itself to the transmission network. STU is responsible for the following.

- Predicting the generation capacity and dispatch by including system reliability, marginal generation costs, future electricity price and future environmental policy, through dedicated models
- Simulation of different scenarios in capacity development and generation despatch for the development of a flexible transmission grid structure
- Integrated resource or least cost planning methods to evaluate the potential capacity addition resources and uncertainties and to determine the best mix of sources

Case Study: Location-specific DER program, California

California's regulations require the investor-owned utilities (IOUs) to submit a Distribution Resource Plan (DRP) proposals to the California Public Utilities Commission (CPUC). The bill directs utilities to identify optimal locations for the deployment of distributed resources by evaluating locational benefits and costs. It also directed the utilities to determine the ability of existing infrastructure to accommodate new resources and the potential for distributed resources to provide safety and reliability benefits.[106]

106 TUS Department of Energy (2018). Integrated Distribution Planning Utility Practices in Hosting Capacity Analysis and Locational Value Assessment. Available at: https://gridarchitecture.pnnl.gov/media/ICF_DOE_Utility_IDP_FINAL_July_2018.pdf (accessed on 18 April 2019).

FINANCING OF BEHIND-THE-METER DREG

Behind-the-meter DREG provides the opportunities of avoiding T&D losses and of deferring investments into upgrading network infrastructure. Especially in the case of utilities or governments that offer subsidised rates to certain consumer categories, utility-driven behind-the-meter DREG programs are commercially attractive, as they often result in avoided costs and losses to the utility. Innovative financing and planning instruments for behind-the-meter DREG will need to be evolved.

Tamil Nadu

There is a great potential for utility-driven DREG for the agricultural sector of Tamil Nadu.

Electricity for operating agricultural pumps in Tamil Nadu is 100% subsidised. Grid-connected solar systems installed at the farms could be financed by, or on behalf of the utility with the investment being recovered from the avoided subsidised electricity supply to the agricultural pumps. The farmer may benefit from an increased reliability of electricity supply and could receive a financial incentive. This incentive could be designed to encourage the farmer to reduce electricity consumption, and to operate the pump at certain hours of the day when grid demand is low

Case Study: Utility-owned domestic rooftop solar

San Diego Gas & Electric's (SDG&E) owns solar plants on leased rooftops of its customers. The rooftop systems are connected to the utility-side of the meter and the electricity flows right into the grid using a gross metering mechanism. The customer does not earn any energy credits nor is there a decrease in his/ her bill.[107]

Case Study: SolarShares Program, Sacramento Municipal Utility District (SMUD)

The SolarShares program allows customers to purchase output from a solar project on a monthly basis, rather than own the system. Electricity from SolarShare systems is fed directly into the grid and SMUD uses this solar-generated electricity as the basis for its SolarShares program. Customers receive monthly kWh credits for the estimated output of their solar subscription. The rate for the kWh of solar is locked-in when the customer enrols, thus solar energy acts as a hedge against future price increases.[108]

Case Study: On-Bill Financing Program, Tallahassee Utilities

The City of Tallahassee Utilities (Florida) has been running a successful on-bill financing program since 1983. The program has enabled the utility's customers to perform energy-efficiency retrofits and other energy projects on their homes with no up-front costs. The utility raised several million dollars in capital for the program before and after its launch through the utility's ratemaking process. When setting the rates for the following year, the utility would set rates higher than its forecasted need, creating an overage. These overage funds were used to capitalize the on-bill loan fund. Customers may borrow up to USD 10,000 (USD 20,000 if solar PV or cool roofs are included) at a

107 Jani, O.; Khanna, R.; Magal, A.; Karandikar, A.; and Awalikar, A. (2016). MNRE – Best Practices Manual for Implementation of State Level Rooftop Solar Photovoltaic Programs in India. Available at: https://www.germi.org/downloads/20160825%20RTPV%20Best%20Practices%20Manual%20Master%20Ver%203.2.pdf (accessed on 17 April 2019).

108 Coughlin, J.; Grove, J.; Irvine, L.; Jacobs, J. F.; Phillips, S. J.; Moynihan, L.; and Wiedman, J. (2010). U.S. Department of Energy – A Guide to Community Solar: Utility, Private and Non-profit Project Development. Available at: https://www.nrel.gov/docs/fy11osti/49930.pdf (accessed on 18 April 2019).

5% interest rate plus 1% processing fee, which help build the revolving loan funds. Customers repay the loans through the monthly utility bill as a differentiated line item over five years (ten years if solar PV or cool roofs are included).[109]

Table 7.3: Enabling Environment for DREG in TN – a checklist.

Instruments available	STATUS: Absent	Emerging	Established
DREG mandates & targets		✓	
Time of-use tariffs		✓	
Location specific tariffs	○		
Technology specific tariffs			☆
Capacity specific tariffs	○		
Ancillary services	○		
Demand Response	○		
Interconnection Voltages, Procedures & Standards		✓	
Smart Grid - advance monitoring and control systems		✓	
Advance metering infrastructure;		✓	
Advanced standards for grid inverters	○		
Advanced forecasting		✓	
Aggregation of DREG	○		
Pro-active planning of DREG capacity addition	○		
Financing of behind the meter DREG		✓	

109 Michigan Saves, Holland Board of Public Works (HBPW), Collaborative Efficiency (CE) and The Environmental and Energy Study Institute (EESI) (2017). Program Design Considerations for Developing an On-Bill Financing Program: A Primer for Utilities in Michigan. Available at: https://www.michigan.gov/documents/mpsc/April_2017_On-bill-primer_for_Michigan_Utilities_560204_7.pdf (accessed on 17 April 2019).

8. RECOMMENDATIONS

In order to integrate DREG in a sustainable energy transformation for Tamil Nadu, a phased approach may be required. This requires new policy and regulatory instruments, appropriate tariff setting and market mechanisms and an integration of DREG into the utilities grid operation and expansion planning as detailed below:

Figure 8.1: Planning for grid integration of DREG.

FOUNDATIONAL
2012 - 2022

GOALS

- DREG is recognised as a technology and commercially attractive generation option to complement conventional power generation.
- Policy & regulations are adapted to incorporate DREG specific requirements and opportunities.
- Tariff rates differential between utility-scale RE systems and DREG.
- Dedicated behind-the-meter programs are being actively promoted by the utility.

RECOMMENDED ROAD MAP

Policy and Regulations

- (Established) 2012 Solar Energy Policy 2012: Net metering mechanism
- (Established) 2019 Solar Energy Policy 2019: Net feed-in mechanism for LT consumers, gross feed-in mechanism at all voltage levels, Consumer Category solar energy target of 3,600 MW by 2022
- Permit interconnection of DREG at any voltage level
- Generation targets for all DREG technologies
- Set targets and regulations for energy storage

Market Design

- Introduce innovative financing tools for behind-the-meter DREG
- Capacity-specific tariffs for DREG
- Set tariffs for energy storage

Planning

- Develop a comprehensive plan to operationalise the Tamil Nadu Solar Energy Policy 2019

TRANSITIONAL
2022 - 2030

GOALS

- A substantial share of new generation capacity addition is on account of DREG.
- Tariff setting becomes more sophisticated and takes into account time- and location-specific value of DREG.
- DREG is an integrated component of the utilities planning system, and interconnection is facilitated on the bases of the grid's hosting capacity.
- Markets for DREG, Storage and DR services such as active and reactive power balancing are enabled.
- Advanced data communication, monitoring and control systems are integrated for a smart grid development.

RECOMMENDED ROAD MAP

Policy and Regulations

- Announce dedicated policy road map for DREG
- Introduce standards for advanced inverters
- Permit aggregation for DREG and Demand Response
- Introduce smart-grid standards
- Introduce advanced forecasting for DREG generation

Market Design

- Compensate for ancillary services
- Incentivize flexible generation and storage
- Introduce compensation model for curtailing of DREG
- Introduce targeted Demand Response Programs and respectve market mechanisms
- Integrate electric vehicle (vehicle to grid) opportunities
- Introduce location-specific value for DREG

Planning

- Proactively plan DREG capacity addition based on network hosting capacity
- Introduce advanced metering infrastructure
- Introduce advanced forecasting at distribution level

TRANSFORMATIONAL 2030 - 2038

GOALS

- The majority of new generation capacity addition is on account of DREG.
- Wholesale markets for dynamic tariffs and aggregators are established.
- Regulations for grid and market integration for electric transport solutions are well established.
- DREG growth scenarios are regularly made resulting in proactive investments to strengthen hosting capacity and efficiency of the distrbution system.

RECOMMENDED ROAD MAP

Policy and Regulations

- Review and update policies and regulations with the experience gained during the transition phase.

Market Design

- Review and update market design to account for emerging and new technologies, system costs and consumer behaviour.

Planning

- Based on the review of policy, regulations and market design, plan for the next phase of DREG integration.

9. GLOSSARY OF TERMS

Definitions for some the frequently used terms in this report.

Advanced Forecasting: It is a mechanism that is used to predict or forecast the probable demand for units of electricity for a period of time. It may use smart meter, sensors, electricity tariff mechanisms to determine and other daily parameters like temperature, humidity and solar radiation that comprises the weather data for forecasting. Along with natural phenomenon such as weather, physical aspects such as traffic flow are also considered.

Advanced Metering infrastructure (AMI): is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers.

Behind-the-Meter Generation: An electricity generating system where renewable energy is being engaged to generate electricity. As the electricity is not generated on the side of the grid it is known as the behind-the-meter generation.

Consumer Category Generation Systems: where the objective is self-consumption of solar energy and export of surplus energy to the grid. For these systems the grid connection is through a consumer service connection of a distribution licensee.

Centralised Generation: A power generation and distribution system architecture based on large-scale power plants that are located centrally in radial utility networks and designed to deliver base-load power that changes very slowly.

Curtailment: According to the 'Wind and Solar Energy Curtailment: Experience and Practices in the United States', NREL, Curtailment is a reduction in the output of a generator from what it could otherwise produce given available resources, typically on an involuntary basis.

Demand Response (DR): Demand response and smart meters are changing the way we consume electricity, allowing users to reduce consumption during peak periods to help balance the grid.

Dispersed Generation: These are decentralised generation systems. They can use both fossil and renewable fuels to generate electricity. They are also known as distributed generation systems.

Distributed Generation: Common examples of such systems include rooftop solar PV units, natural gas turbines, micro-turbines, wind turbines, biomass generators, fuel cells, tri-generation units etc.
Distributed Renewable Energy Generation (DREG): Distributed generation that is renewable such as rooftop solar PV units, wind turbines, biomass generators etc.

Distributed Energy Resources (DER): A wider term than Distributed Generation. DERs include behind-the-meter renewable and non-renewable generation, energy storage, inverters, electric vehicles and other controlled loads. DER also comprises new technology like smart meters and data services.

Embedded Generation: Embedded generation refers to the generation of electricity using power stations connected directly to the electricity distribution network.

Gird Parity: Gird parity occurs when an alternative energy source can generate power at a levelised cost of electricity (LCOE) that is less than or equal to the price of power from the electricity grid.

Hosting Capacity: The amount of DREG that can be accommodated without adversely affecting power quality, as well as reliability under existing control configurations, and without the need for extensive infrastructure upgrades.

Levelised Cost of Energy (LCOE): LCOE defines the unit cost of electricity generation over the life of a power plant.

Market Maturity: It is the stage when the market has reached its equilibrium, where there is no more scope of growth or innovation in the market.

Microgrid: A microgrid is an energy system of distributed energy sources which include generation, demand management systems, storage and loads in an interconnected form. A microgrid can be a grid-connected system or a system that works disconnected from the grid in an island mode.

On-Site Generation: On-site generation refers to the generation of electricity at the point of consumption i.e. on the site. These systems have the advantage of consumption at the point of generation, thus the electricity generated does not have to be transmitted to long distances. It is also known as distributed generation.

Personal Power Plants: Small generation systems that are typically owned by individuals, usually located at their homes such as rooftop solar for example.

Ramping Reserve: Is the ability of a generation facility or energy resource to stop or start on command in order to meet the electricity grid's variable demand. As load fluctuations accompany solar and wind generation, fast-ramping resources are a must for grid stability.
A ramping event is defined as a large change in the magnitude of the net load (at least 50% of installed capacity) within a time interval of up to 4 hours. The ramp rate is the amount of time required for output to increase or decrease.

Smart Grid: A power generation and distribution system that incorporates "Big Data" acquisition from large numbers of sensors and monitoring devises throughout the grid for data processing.

Smart Metering: A smart meter is a digital meter that replaces the old analog meters used to record a consumer's electricity consumption. Smart Meters enable two-way communication between the meter/consumer and the supplier/utility. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC).

Spinning Reserve: This is the excess capacity of the grid to generate electricity over the supply load. It allows for the grid to generate and supply electricity at the time of a sudden surge in demand or if there is a case of generator loss. It is an online reserve capacity synchronized to the grid. It helps maintain system frequency stability in unforeseen or emergency operating conditions like sudden load swings.

Utility Category Generation Systems: where the objective is sales of solar energy to a distribution licensee or a third party or self-consumption at a remote location (wheeling). For these systems the grid connection is through a dedicated gross metering interface

ANNEXURE I

Assumption	Solar PV	Wind
Auxiliary Consumption (% of generation)	0.00%	0.00%
Capacity utilisation factor	19%	29%
Grid availability factor	95%	95%
Annual degradation	1.00%	1.60%
Operation and Maintenance Expenses in year 1	1.40%	1.1% (85% of investment) 0.22% (15% of investment)
Annual increase in Operation and Maintenance Expenses	5.72%	5.00%
Insurance (% of depreciated asset value)	0.35%	0.35%
Equity	30%	30%
Loan tenure (years)	10	10
Moratorium (years)	1	1
Interest on loan	10.55%	9.95%
Working Capital - O&M (months)	1	1
Working Capital – Receivables (months)	2	2
Interest on Working Capital	11.55%	10.95%
Depreciation Rate	3.60%	3.60%
Discount rate	9.53%	8.75%
Return on Equity	17.60%	17.56%
Economic Life (years)	25	25

ANNEXURE II

Assumption	Biomass	Bagasse	Small Hydro
Auxiliary Consumption (% of generation)	10%	8.50%	1%
Capacity utilisation factor	80%	55%	30%
Station heat rate (kCal/kWh)	3,840	3,240	
Calorific value (kCal/kg)	3,200	2,300	
Fuel rate (INR/MT)	2,967.35	1,834.35	
Operation and Maintenance Expenses in year 1	5% (85% of investment) 0.9% (15% of investment)	22.34 lakhs / MW	22.35 lakhs / MW
Annual increase in Operation and Maintainance Expenses	5.72%	5.72%	5.72%
Equity	30%	30%	30%
Loan tenure (years)	10	10	13
Moratorium (years)	1	1	
Interest on loan	9.95%	9.95%	10.41%
Working Capital – O&M (months)	1	1	1
Working Capital – Receivables (months)	2	2	2
Interest on Working Capital	10.95%	10.95%	11.41%
Depreciation Rate	4.5%	4.5%	First 13 years: 5.28% After: 0.97%
Return on Equity	17.56%	17.56%	17.60%
Economic Life (years)	20	20	35

December 2019