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Bringing unlike minds together

Zero to Green

Buildings for Planet and Profit

Acknowledgments

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Conceived by

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Knowledge Partners

IGBC, PKC, CII Confederation of Indian Industry, IIT Madras

Implementation Partners

Solar: Cleantech Solar, First Solar, cygni

Wind: sembcorp, Envision

Storage: LOG9, Leclanché Energy Storage Solutions, Danfoss, DUBAS

EMS: CEET, NSE

Supporting Partners

NSE, IESA India Energy Storage Alliance, Department of Heavy Industry, Government of India

Disclaimer

The data and computations in this report are based on the estimates of IIT Madras Research Park located in Chennai, Tamil Nadu. The systems described include pilot projects developed, tested, and demonstrated at the Research Park campus.

Supporting Note from Partner: CII IGBC

"We are glad to acknowledge the pioneering work undertaken by IIT Madras Research Park in implementing innovative energy storage solutions: Thermal storage and Grid-scale battery storage systems at the IIT Madras Research Park campus. The successful demonstration in a commercial building not only showcases the technical feasibility but also underscores the economic viability of such sustainable solutions.

From the CII Indian Green Building Council (IGBC), we congratulate the IIT Madras Research Park team involved in this flagship project and extend our wholehearted support to this commendable initiative. We are eager to collaborate and assist in promoting the IIT Madras Research Park as a prominent and successful case study in the Indian buildings sector.

We take this opportunity to highlight IGBC's significant endeavour—the launch of the Mission on Net Zero in 2021, coinciding with Earth Day. The vision of this initiative is to facilitate 'India to become one of the foremost countries in transforming to Net Zero by 2050'. The IIT Madras Research Park project and "Zero to Green" approach will play a pivotal role in guiding the Indian buildings sector towards embracing the Net Zero Energy transition. It is through such collaborative efforts and pioneering initiatives like this one that we can collectively pave the way for a sustainable and environmentally responsible future for India and the world."

Mr Ajit Kumar Chordia
Chairman, IGBC Chennai Chapter
Managing Director, Khivraj Tech Park Pvt. Ltd.

Contents

Executive Summary

Today, India's building sector accounts for around 160 million tons of CO_2 emissions[1] and nearly 30% of the nation's electricity consumption[2]. If conscious methods are not swiftly undertaken the buildings sector is projected to emit seven times more CO_2 by 2050, as compared to 2005[3] levels. Despite the urgent calls towards addressing the rising threats of climate change, adopting renewables has not been widely undertaken due to the high capital cost and the misconception of cost competitiveness against traditional fossil-fuel based sources. In this report, we point out that most of these reservations are misplaced. In fact, renewables today are so placed, that adopting them for the buildings sectors will save money for users. We therefore aim to highlight the current scenario, technology considerations and the transition plan towards decarbonization of the buildings sector. We take an in-depth look at IIT Madras Research Park as a showcase project that demonstrates the technology readiness and economic viability of moving towards renewable power sources to meet its energy requirements today.

The cost of renewables has drastically reduced in the past decade enabling it to be a highly competitive source of electricity in the open market. At the same time, the state electricity tariffs of the commercial category are at least 40% higher than industrial and residential tariffs making it the first sector ripe for change. Given its higher expenditure incurred on electricity presents an excellent opportunity for commercial complexes to move towards renewables whilst also enabling cost savings. The cost competitiveness, in addition to technology readiness along with supportive policies by the government help us envision a pathway towards a fully renewable powered commercial complex. Given the fact that about 70%[2] of India's urban infrastructure is yet to be built, signals a huge opportunity for not only existing buildings but also for a large portion of the buildings yet to be constructed to take up a similar approach towards sustainable energy solutions. The report details the technologies, costs, and varying economics of adopting Renewable Energy based systems that highlight the promising potential for commercial consumers to save up to 30% on electricity costs. Declining costs of solar, wind and storage systems further the prospect for even lower costs and higher savings, thereby showcasing a pivotal moment in the Net-Zero energy transition journey.

[1] Greenhouse gas emissions by sector, India (2019)
[2] BEE India – Energy Efficiency in Buildings
[3] RMI India- India's Buildings Sector Moonshot

1. Introduction

Growing urbanization shows that 40% of India's population or around 600 million people are projected to reside in urban areas by 2030[4]. It is estimated that from now until 2030, India will need to build 700 - 900 million square meters of urban space every year. In other words, India will have to build a new Chicago city footprint every year until 2030 to meet its growing urban demand. Buildings, both big and small are increasing in number across all our cities and urban areas, its rapid rise signals an ever-increasing energy footprint. As India's economy and energy consumption grows, its carbon footprint is also estimated to grow exponentially. The decoupling of GDP and Emissions increase is important for any country, but for India it becomes a crucial factor in its pursuit for sustainable growth.

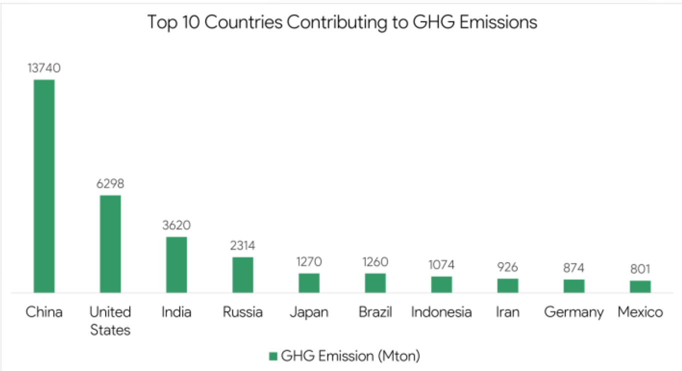


Fig 1.1 Top 10 Countries contributing to GHG emissions.

Currently, 76% of India's electricity supply comes from Coal and Crude Oil sources. As of 2022, India stands as the 3rd largest Greenhouse Gas (GHG) emitter in the world[5] as shown in Fig 1.1. The major contributors to India's GHG emission are evidently electricity and heat. The residential, industrial, and commercial categories account for close to 75%[6] of the country's electricity usage, which is primarily powered by fossil fuels as shown in Fig 1.2

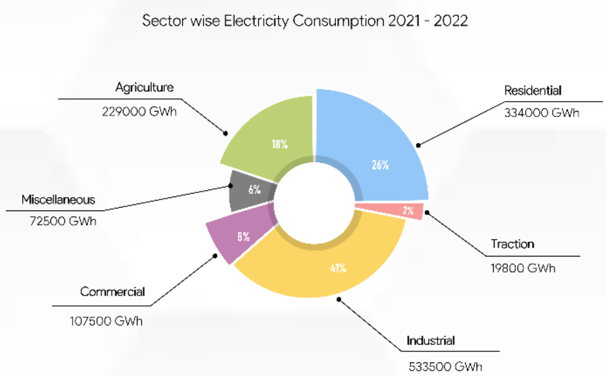


Fig. 1.2: All India Electricity Consumption Sector Wise Utilities and Non-Utilities for FY 2021-2022

At the same time, India also consumes much lower energy than most other countries in the world when we look at per capita emissions, with a country ranking list placing it at a 103rd in the world.

4 India's urban awakening: Building inclusive cities, sustaining economic growth-McKinsey Global Institute
5 GHG emissions of all world countries, 2021 report
6 MOSPI, Energy Statistics 2023

The dichotomy of a large population very much in its development cycle growing rapidly looms tall. India's growth, especially in its energy footprint could be pivotal in the entire planets effort towards addressing the rising threats of climate change. Decarbonization of the electricity sector, particularly in the commercial, industrial, and residential category will be a big step in combating the growing threats of Climate change.

India's vast potential when it comes to Solar and Wind offers a ready means to decarbonize and increase the share of renewable energy. Over the recent past, technology advancement and declining costs have led to massive deployments of renewable capacity across the country, with a 300% growth in Solar and Wind based power generation in the last 10 years.

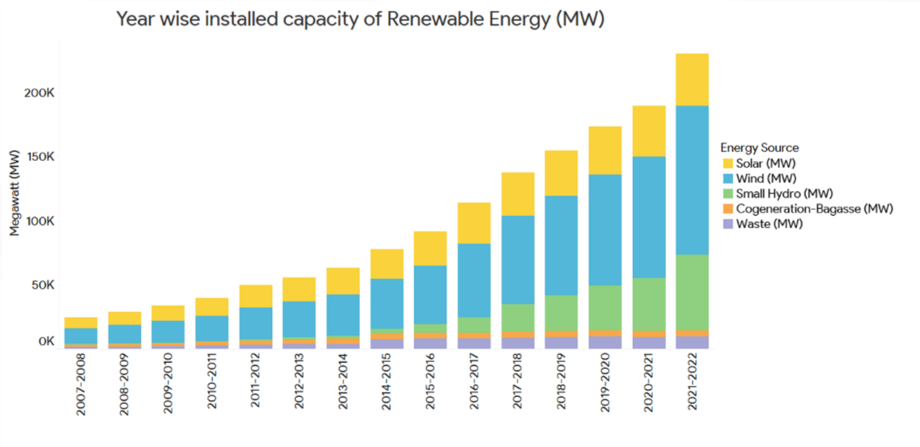


Fig 1.3 Year wise installed capacity of Renewable Energy[7]

Adopting renewable energy has not only played a pivotal role in helping India's effort towards addressing climate change, but also brings with it a massive economic opportunity for large-scale cost-savings. Solar and Wind based energy in India is among the cheapest forms of energy generation available anywhere in the world, the costs have reached such an inflection point that both developing and developed countries have a compelling reason to phase out fossil fuels, meet their growing energy demands, and save on costs in the process. Today, moving towards low-carbon energy systems is a real opportunity for buildings, communities, and corporations to wholly embrace, whilst also creating value for self and society at large.

2. Current Scenario of Commercial Complexes

India has approximately 40,000 commercial complexes which include office buildings, research centres, shopping malls, restaurants, etc. The number of commercial complexes is expected to triple by 2030, compared to 2010 estimates. Today, these complexes collectively consume 8% of India's total electricity consumption whereas the industrial sector accounts for roughly 41% of the electricity consumption. The price of electricity is also the highest for the commercial category, which makes it ripe for disruption.

The per unit tariff for commercial consumers is on an average 40% higher compared to residential and industrial tariffs across all states in India.

7 Year wise installed capacity of Renewable- IITMRP National Energy Dashboard

We look at one such commercial building complex, the IIT Madras Research campus located in Chennai, Tamil Nadu as a case study. At 1.2 million sq. Ft, housing over 200 R&D centres, offices and startups, the Research Park is akin to a typical commercial or office building complex in the country. The prevailing tariffs, consumption patterns and cost computations are presented for a comprehensive analysis of the current energy scenario in a typical commercial building complex setup. The calculations are made considering that the primary consumption is from the state electricity grid and a backup system in the form of a diesel generator. The first step to be considered for the cost computation is identifying the applicable category under the state's electricity tariff.

The per unit (kWh) energy charges for Commercial consumers as per the state DISCOM, TNEB (Tamil Nadu Electricity Board) are priced at ₹8.70 or ₹9.70 per unit based on consumer category as tabulated below.

Type of consumer	Energy charges (₹/unit)[8]	Demand charges (₹/kVA/month)
High Tension Tariff III	8.70	562
Low Tension Tariff V		
0-50kW	9.70	102
Above 50-112kW	9.70	307
Above 112kW	9.70	562

Table 2.1.1 TNEB Tariff applicable to commercial complexes.

In addition, according to The Tariff Order as per July 2023, the tariffs vary based on peak hours and rebate hours for all High-Tension (HT) consumers. The Tariff Order states that:

'All HT consumers except HT-IIA (Lift Irrigation), HT-IV and HT-V (e-vehicle PCS) shall be billed at 25% extra for FY 2022-23 to FY 2026-27 on the energy charges for the energy recorded during peak hours. The duration of peak hours shall be morning 6.00 A.M to 10.00 A.M and evening 6.00 P.M to 10.00 P.M'.

Based on the above statement the per unit charge for High Tension Commercial consumers during peak hours are as follows:

Category	Rebate Hours (5% less)	General	Morning Peak Hours (25% more)	General	Evening Peak Hours (25% more)
Time	10:00 pm - 5:00 am	5:01 am - 5:59 am	6:00 am - 9:59 am	10:00 am - 5:59 pm	6:00 pm - 9:59 pm
Tariff	₹8.27 / unit	₹8.70/ unit	₹10.88 /unit	₹8.70/ unit	₹10.88 /unit

Table. 2.1.2: TANGEDCO Time of Day rates for Commercial Building

The second step is to understand the energy profile of the building. This includes information on daily, monthly, and annual consumption from the grid, from the backup sources and the average

8 TANGEDCO Tariff order,2023-2024

peak demand recorded for the building. Here, the Sanctioned load means the maximum load /demand in kW/kVA applied for by the applicant and agreed to by the Electricity Board which, if breached the consumer will be penalised for. This number refers to the amount of power that can be drawn from the grid at *any instant*. The term 'Demand Charges' stands for the cost paid per kVA of sanctioned demand.

The following numbers are based on the monthly consumption recorded at IIT Madras Research Park based on data from 2022:

Factors considered	Values
Average Monthly Energy Consumption from Grid	12,73,790 kWh
Monthly Energy Consumption from Diesel Generator	18,011 kWh
Sanctioned Demand	5000 kVA
Demand Charges	₹562 / kVA
Average Peak Recorded Demand per month	3397 kVA
Meter Rent	Inclusive of 18% GST
Diesel Cost	₹94.24/ Litre

Table 2.1.3 Assumptions considered for calculations of a commercial complex.

Based on the above assumptions the monthly per unit cost for IITM Research Park in the year 2022 is tabulated in Table 2.1.4 with reference to a commercial complex. Out of the total ₹12.31 per unit rate, the demand charges and the peak hour charges are ₹2.08 and ₹0.64 respectively per unit, which constitute nearly 25% of the total per unit cost.

Particulars	Units (kWh)
Commercial	12,73,790
Diesel Generator	18,011
Total	**12,91,801**
Particulars	**Per unit rates (₹/ kWh)**
Commercial	8.70
Diesel Generator	31.33
Particulars	**Overall average rates (₹/ kWh)**
Consumption charges/unit	8.70
Demand charges/unit	2.08
Peak Hour consumption cost/ unit	0.64
E-Tax + meter rent /unit	0.57
Average rate without DG	11.99
Average rate with DG	12.31

Table 2.1.4 Per unit cost for a commercial complex

Electricity tax (E-tax) = 5% *x* (Actual energy charges + Peak hour energy charges + recorded demand charges + Low Power Factor penalty charges)

Peak Hour consumption cost/ unit = Consumption during peak hours *x* Tariff rate during peak hours

3. Transition Plan towards Renewables

Shifting consumption to renewable sources require setting up infrastructure for renewable energy generation, energy storage systems and a robust management system that can effectively balance demand and supply on a real-time basis. One of the immediate steps that buildings are taking in the pursuit to green energy is setting up Rooftop solar systems on their buildings. However, due to the energy intensity of commercial buildings and limited space available on rooftops one will not be able to meet all the energy requirements on site through rooftop solar.

Rooftop solar power can only meet up to 5 - 10% of a commercial complex' electricity requirements in India which is insufficient for a building attempting to reduce its dependency on the grid and reduce electricity cost in the long run.

Despite the large deployment of renewable capacity in the country, the actual energy generated from renewable sources add up to only about 15% excluding large hydro. One therefore needs to look beyond the physical location of the building for increasing the share of renewables and meeting the energy requirements of a building. Today, it is possible for buildings to explore such an option through the Open Access policy of the Government of India. The policy permits users to wheel in renewable energy from solar / wind plants located at a distance using the existing grid infrastructure. A consumer can avail the benefits of cheap and green renewable power by setting up their own solar or wind plant under this policy. However, RE generation alone is not sufficient given the inherent variable nature of Solar and Wind. To ensure there is a balance between demand and supply, energy storage and its optimal management also become key. The pathway towards an RE powered complex is displayed in Fig 2.1 as a roadmap.

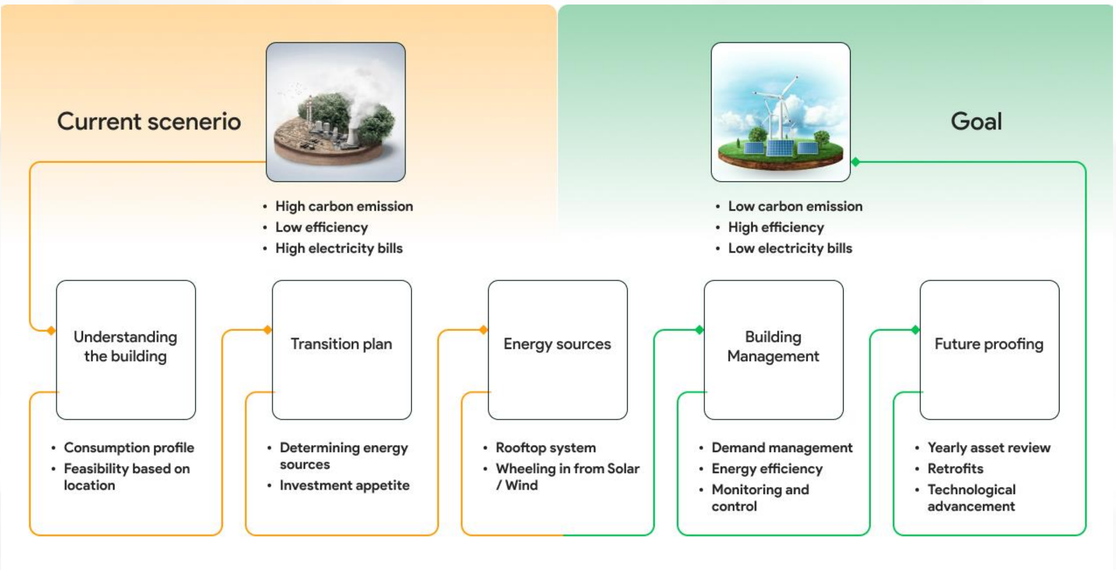


Fig. 2.1: Roadmap towards a renewable commercial complex

3.1. Energy Generation – Cost Efficiency of Solar and Wind

India has set ambitious goals of increasing renewable capacity to 500 GW by 2030[9], which includes installation of 280 GW of solar and 140 GW of wind[10]. The steep decline in costs have resulted in large scale adoption of solar and wind across the country. The Levelized Cost of Energy (LCOE)[11] estimates in the past decade for various renewable sources are displayed in Fig. 3.1.1. The cost of solar has dropped by 86% and wind by 60% in the last ten years making them the most affordable options.

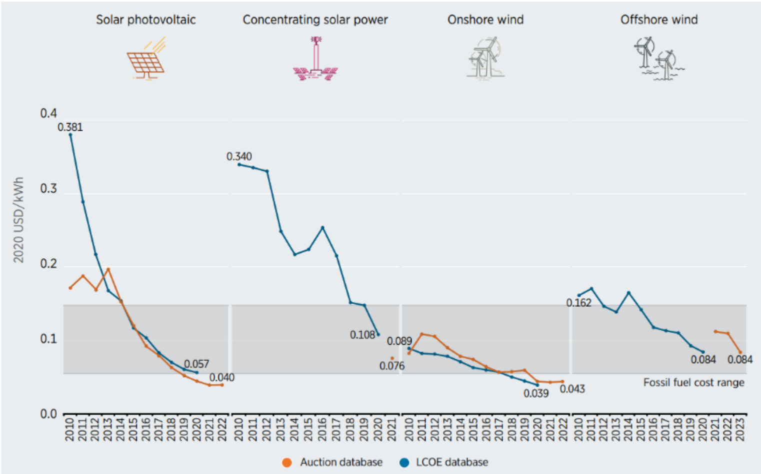


Fig. 3.1.1: Change in LCOE (USD) of electricity cost from 2010-2020

Owing to the declining cost of renewables and the added advantage of Open Access, the possibility of 100% RE becomes a reality.

While open access does away with limitations of rooftop solar such as scalability, Solar and Wind energy remains constrained due to its inherent intermittency or lack of controllability. To enable system wide change towards renewables, the flexibility of dispatching power as and when it is required will be crucial. The solar and wind generation follows a typical hour wise pattern as displayed in Fig. 3.1.2

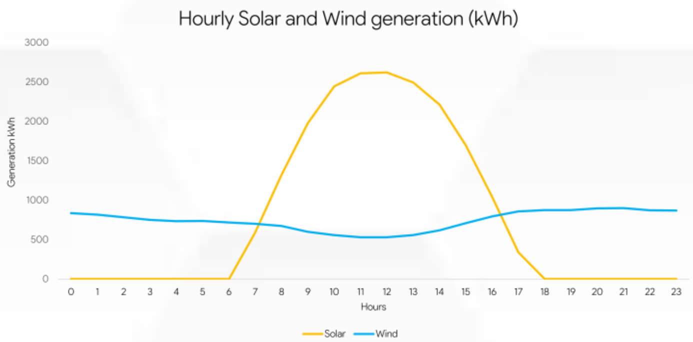


Fig 3.1.2 Average Hour wise variation of Solar and wind energy generation in Tamil Nadu

[9] Renewable Energy in India
10 India gets closer to meeting 2030 renewable energy targets with new transmission plan
11 LCOE = Total Cost over a system's lifetime / Total Power produced over the lifetime.

This generation pattern is not suitable to continuously support the varying consumption of a building. The demand pattern on an average day of IITMRP is displayed in Fig. 3.1.3

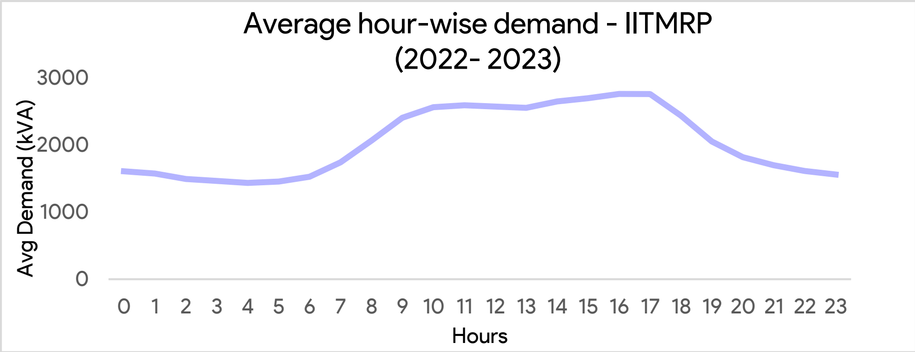


Fig 3.1.3 Demand variation across 24 hours at IIT Madras Research Park

Apart from hourly variation across the day, the generation patterns of solar and wind energy also vary across months. While Solar remains constant with small seasonal variations, Wind is highly seasonal with the bulk of the generation happening across a few months as shown in Fig. 3.1.4

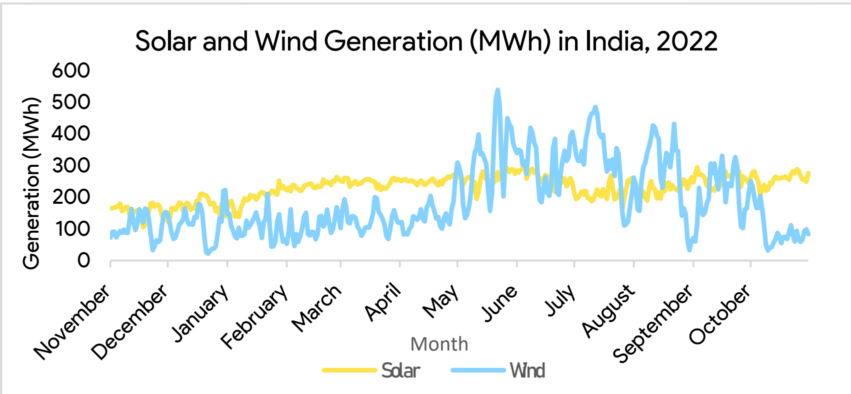


Fig 3.1.4 Seasonal variation of Solar and Wind energy

Thermal and gas-based power-plants are eminently suitable to respond to this demand, but nature-based solar and wind plants are inherently variable. The only way to overcome the hourly/ seasonal deficit of renewable energy is by adding flexibility to it through energy storage systems.

3.2. Mind the Gap: Energy Storage

Energy storage systems are essential to balance intermittency of the renewable energy sources. Depending upon the requirement, type of technology[12], and economics one may select from options such as battery energy storage, pumped hydroelectric storage, large flywheels, thermal energy storage, compressed gas energy storage or hydrogen-based energy storage amongst others. Pumped hydroelectric or compressed gas-based energy storage involves huge capital investment, battery energy storage or thermal systems are generally more modular in design. Amongst these systems thermal and chemical battery storage systems are found to be the most

[12] S. Koohi-Fayegh, M.A. Rosen (2020) A review of energy storage types, applications and recent developments, Journal of Energy Storage, Volume 27, 2020, 101047.

suitable for the type and means of consumption at commercial complexes. As per studies the cost of batteries is said to drastically decline in the coming years as displayed in Fig. 3.2.1

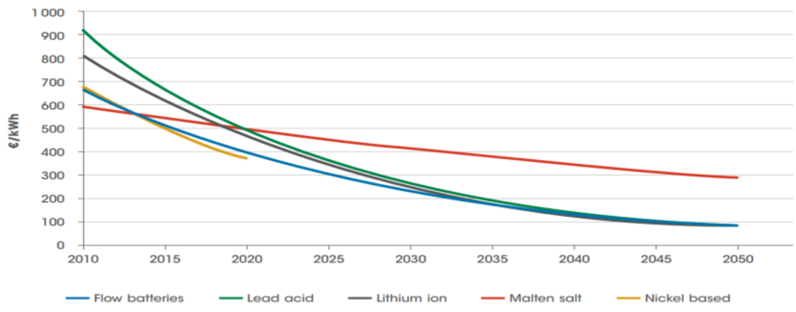


Fig. 3.2.1: Decline in various battery chemistry cost (pounds) across the years

3.2.1. Thermal Storage

40% of a commercial building's energy is utilised in air conditioning. Thermal energy storage systems store energy in thermal gradients (temperature differences) either as chilled or hot water. It is obtained by continuously heating or cooling the storage system. It can precondition and store energy in the form of working fluid of the thermal energy storage, and this in turn can be used whenever the renewable energy is in deficit or absent, thus making it an attractive form of energy storage. In the future, chillers operating with advanced solutions like Phase Change materials such as hydrates will result in higher storage capacity by reducing the volume which could be a way to improve its viability, especially is commercial building like setups.

Fig. 3.2.2: Thermal Storage capacity of 3 lakh litres set up in IITMRP

3.2.2. Battery Storage

Various battery technologies use different chemical compounds to store electricity. Each of these technologies have other characteristics and are used to store and release electricity for different durations ranging from a few minutes to several hours.

Lithium-Ion Batteries are lightweight and have high energy density. Interest in the electric vehicle space has increased demand for lithium batteries. The global capacity of these batteries is expected to be 4 times the current state by the end of this decade. Recent advancements in various cell chemistries, especially in Li ion-based energy storage systems has brought down costs significantly, improved calendar life and number of cycles, making it a more favourable choice for both large and small sized energy storage systems. [13]

3.3 Stitching Together: Energy Management System

The way we use renewable energy is as important as implementing it. Efficiently managing demand and supply between available renewable and grid power sources along with utilizing appropriate storage systems is essential and can also help in optimization for reducing the total operating costs incurred.

An Energy Management System (EMS) provides a gateway to achieve energy optimization of various energy sources. Design and control of systems can help drive energy efficiency and increase the overall Energy Performance Index (EPI) of the building. Developing an algorithm based on the data patterns and establishing an intelligent control system is accomplished by using an Energy Management System. Despite the large number of systems in use and energy consumed in buildings, information on their performance is typically not available. A comprehensive energy management system will help drive sustainably powered high-performance buildings that are both comfortable to its occupants and save costs to its owners.

Efficiently utilising storage systems includes identifying the right duration to charge and discharge the storage systems based on the peak demand and peak charges. The Research Park has introduced a factor termed as ‘Demand Load Factor (DLF)’.

Demand Load Factor is defined as the average utilization of the maximum contracted demand by consumers. Increasing the DLF% would reduce cost per kWh significantly.

A strategy to increase DLF % and thereby reduce Maximum Demand Charges per kWh is to install local energy storage and draw power uniformly, which is detailed in Appendix 1[14]. Currently, we are consuming the maximum demand for only 30% of the time but by consuming the maximum demand for 100% of the time the demand charge will reduce from ₹2.60 to ₹0.78 as calculated in Appendix 1.

4. The Research Park Showcase

The team at the IIT Madras Research Park conducted a comprehensive analysis to understand the consumption patterns at a granular level to determine the energy requirements of the campus at an hourly, daily, monthly, and yearly level based on historical data. Projections based on the same have also been estimated for ascertaining future requirements. The hourly consumption is displayed in Fig. 4.3

13 Ashok Jhunjhunwala, Kaushal Kumar Jha, Anson Sando, IEEE Weiner Conference, some steps for India to move towards 100% Renewable Energy

[14] Appendix 1 - Demand Load Factor (DLF)

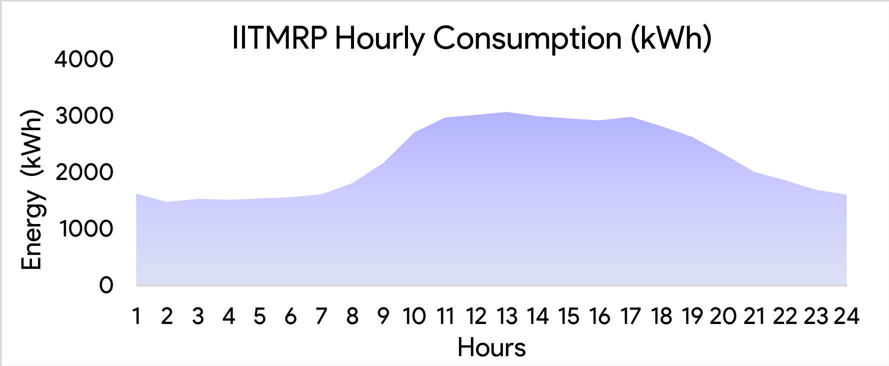


Fig. 4.3: IITMRP Hourly Generation

Once a detailed analysis of consumption levels and patterns was completed, the potential options for converting the consumption to RE based sources was taken up as seen in Figures 4.4 and 4.5

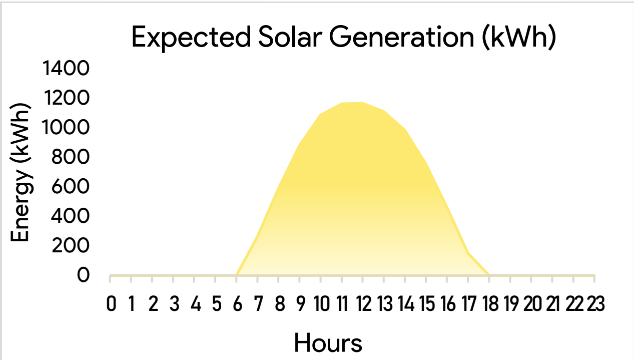


Fig. 4.4: Hourly Generation from 4MW Solar

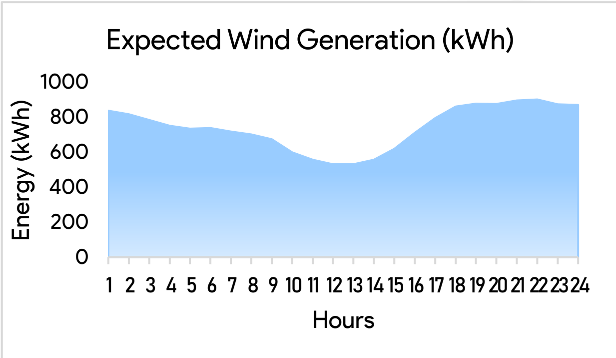


Fig. 4.5: Hourly Generation from 2MW Wind

After careful consideration, the sizing of the renewable capacity is taken up to meet the requirements of the campus. The generation patterns from the Solar and Wind plants are then analysed to determine the excess generation across each hour, day and month of the year. The storage capacity is then accordingly estimated to meet the given requirements.

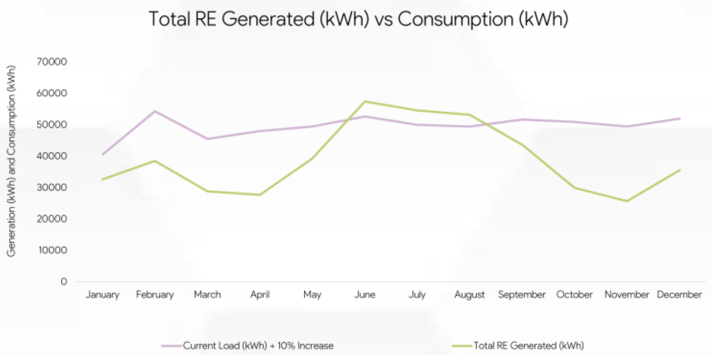


Fig. 4.6: Monthly variation between RE Generation and Consumption in IITMRP

Based on the current consumption profile of the Research Park a total of 4 MW of solar power and 2 MW of wind power with an additional of 1 MW from Rooftop solar supported by a Lithium - ion battery storage of 7898 kWh is estimated to help IITMRP move towards 90% of renewable energy. The computations of these estimates are detailed below in Appendix 3[15]

Fig. 4.7: Rooftop Solar at IITMRP

Fig 4.8: Wheeled in Solar for IITMRP

There are 4 factors contributing to the RE Transition

1. Cost of Renewable Energy (Solar/ Wind)
2. Cost of Storage
3. Transmission and Distribution
4. Losses

4.1 Cost of Renewables

For the Research Park, 4 MW of solar energy and 2 MW of Wind is wheeled in using the Open Access Policy. Both the solar and wind plants are obtained through the Group Captive mechanism. In this CAPEX (Capital Expenditure) model, the corporate buyer for a utility-scale renewable project makes a partial upfront capital investment and co-owns the power-generating asset. Current policy requires corporate buyers to also hold a minimum of 26% of the equity in a project and requires consumption of at least 51% of the power generated from the plant, which is executed through a Power Purchase Agreement (PPA). Based on the investment required, the capital cost of renewables per MW for IITMRP varies between ₹32,00,000 till ₹45,00,000 for fixed solar deployments and solar with tracker respectively, and the capital costs of wind systems go up to ₹1, 50,00,000 per MW. A breakup of the total costs for setting up a solar and wind plant is provided below for reference.

[15] APPENDIX 3- Percentage of RE Going into Storage

Factors involved	1 MW Solar without trackers		1 MW Solar with trackers		1MW Wind	
	Total Cost	Investment through Group Captive Mechanism	Total Cost	Investment through Group Captive Mechanism	Total Cost	Investment through Group Captive Mechanism
CAPEX Cost (₹)	4,00,00,000	32,00,000	5,00,00,000	45,00,000	7,50,00,000	1,50,00,000
Land Required	3.5 acres		4.5 acres		1.5 acres	

Table 4.1.1 Investment cost of renewables

The prevailing per unit tariffs for solar between 2021 – 2022 based on recent auctions held, varies between ₹2.15 – ₹3.11, and the per unit tariffs for wind have varied from ₹2.43 – ₹3.50 from 2017 – 2022 as shown in Fig 4.9 and 4.10

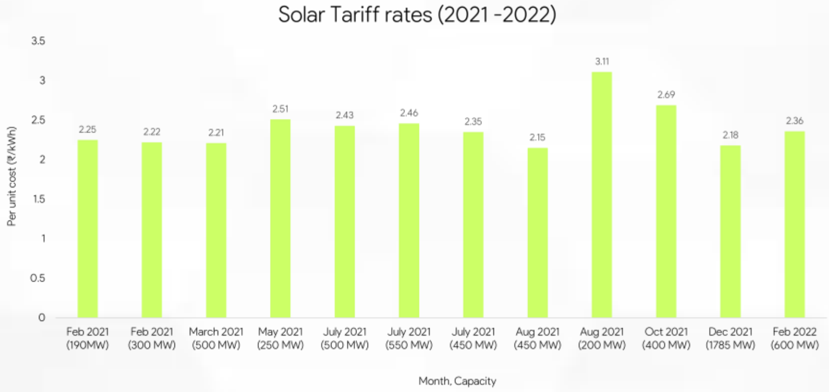


Fig. 4.9: Tariff rates for Solar Energy in India[16]

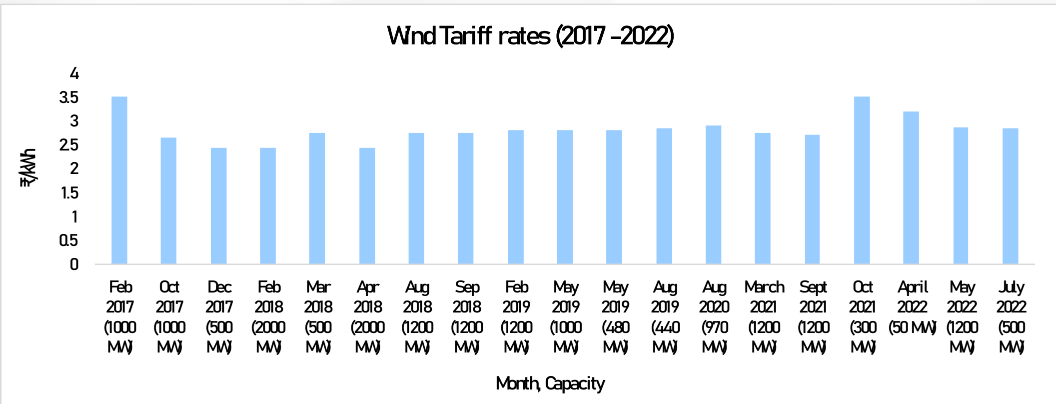


Fig. 4.10: Tariff rates for Wind Energy in India[17]

[16] Solar Tariffs 2021-2022, India- CareEdge Ratings
[17] Wind Tariffs 2017 – 2022, India -MERCOM India Research

4.2 Battery Storage

Two kinds of Lithium-ion cells are taken into consideration for use in the battery storage systems at IITMRP. One is a higher-end variant of Nickel, Manganese and Cobalt (NMC) cells giving about 10000 cycles, with battery pack costs under ₹20k per kWh for a one MWh battery or larger system. The other is a lithium-titanium-oxide (LTO) cell with about 15000 cycles and battery pack costs at around ₹40K per kWh. The cost of LTO batteries goes up from ₹4 per kWh at 2% interest rate (prevalent in the West) to ₹12 per kWh at 10% interest (prevalent in India and other emerging countries). The cost of capital is of huge significance and the storage costs would sky-rocket if interest rates are high as detailed in Table 4.2.3. One therefore must ensure that the capital costs are low, even if the number of cycles are lower. Given the high cost of capital in India, the Li-ion NMC batteries score better than LTO batteries, as interest rates typically tend to be much higher comparatively. Judicious use of solar and wind may get us to have 1.5 cycles to 2 cycles per day, and a higher number of usage cycles also play a role in bringing down the total costs as depicted in the sensitivity analysis presented in Fig. 4.2.1.

Based on the above the cost computation of a Li-ion battery is tabulated below:

Factors considered	Values
Capital Cost (per kWh)	₹ 19,085
Usable Life cycles	10000
Average Capacity Utilization	50%
Interest Rate %	10%
Charge-discharge cycles used per day	1.5
Depth of Discharge %	90%
End of Life %	50%
Usable Battery Capacity kWh	0.675
Battery Life in years	9
Battery Cost per year	₹ 3,284
Battery Cost per kWh (₹/kWh)	₹ 8.89
Battery Cost per kWh Assuming 30% usage (₹/kWh)	₹ 2.67

Table. 4.2.1: Li-ion NMC battery per unit cost computation

The capital cost of storage is calculated based on the numbers computed by IITMRP for establishing a 1 MWh Storage system as tabulated in Appendix 2A[18]. Based on the capital cost, number of cycles, interest rate, Depth of Discharge, and usability, the per unit battery cost is computed to be ₹ 8.89 for Li-ion Storage for the system deployed at the Research Park.

Sensitivity Analysis:

i) Proportion of RE going into Storage:

To determine the battery size, the percentage of RE to be stored in the battery system based on energy generated by the source needs to be estimated. Table 4.2.2 depicts the variation of 40%,

[18] Appendix 2A- Capital Cost of Lithium-Ion Battery Storage

30%, 20%, 10% of the generated renewable energy to be stored in the battery and the cost estimates for each. We see that the savings per kWh varies all the way from ₹1.01 per unit for 40% RE usage through storage and goes up to ₹3.68 per unit for 10% storage.

Proportion of usage	60:40	70:30	80:20	90:10
Tariff Rate + 5% E- Tax (₹)	9.14	9.14	9.14	9.14
Landed Cost of Renewable (₹)	4.57	4.57	4.57	4.57
Storage Cost per Unit (1.5 cycles) (₹)	3.56	2.67	1.78	0.89
Weighted Landed cost per kWh (₹)	8.12	7.24	6.35	5.46
Savings per kWh (₹)	1.01	1.90	2.79	3.68

Table. 4.2.2: Sensitivity analysis based on percentage of storage.

Based on the above computations and the estimated generation patterns from the Solar and Wind plants along with the IITMRP consumption profile we see that close to 70% of the energy can be utilized directly and 30% goes through storage as it helps us save costs and manage power in times of intermittency appropriately.

ii) Cost of Capital – Interest Rate:

Based on a battery cost of ₹19,085, a usable life of 10000 cycles and a 1.5 discharge cycles per day usage, the variation in interest rate between 7% - 12% is computed in Table. 4.2.3 which shows the per kWh cost varying between ₹7.84 to ₹9.61 respectively.

	1.5 Cycles					
Battery Cost	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085
Usable life cycles	10000	10000	10000	10000	10000	10000
Average Capacity Utilization	50%	50%	50%	50%	50%	50%
Interest Rate %	**7%**	**8%**	**9%**	**10%**	**11%**	**12%**
Charge-discharge cycles used per day	1.5	1.5	1.5	1.5	1.5	1.5
Depth of Discharge %	90%	90%	90%	90%	90%	90%
End of Life %	50%	50%	50%	50%	50%	50%
Usable Battery Capacity kWh	0.675	0.675	0.675	0.675	0.675	0.675
Battery Life in years	9	9	9	9	9	9
Battery Cost per year	₹ 2,898	₹ 3,024	₹ 3,153	₹ 3,284	₹ 3,417	₹ 3,552
Battery Cost per kWh (₹/kWh)	₹ 7.84	₹ 8.18	₹ 8.53	₹ 8.89	₹ 9.25	₹ 9.61

Table. 4.2.3: Sensitivity analysis based on interest rate

iii) Usage Cycles of storage per day:

Based on a usage of 1 cycle, 1.5 cycles and 2 cycles a day for different interest rates the cost per unit is shown to vary between ₹7.84 – ₹9.61 for 1.5 cycle per day with the interest rate varying between 7% - 12%.

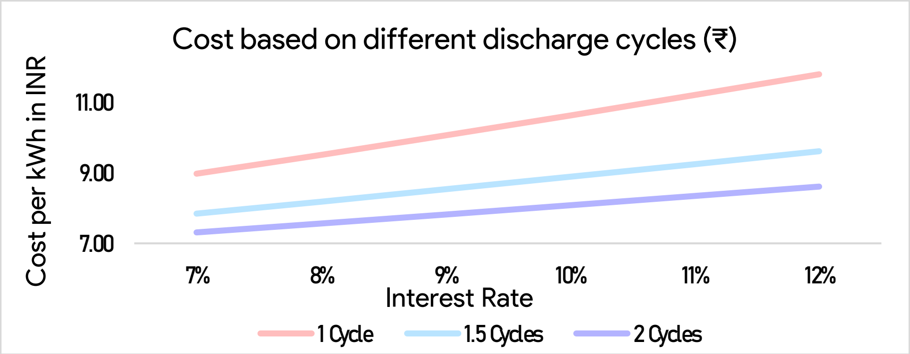


Fig. 4.2.1: Sensitivity analysis based on discharging cycles in a day.

The savings per kWh by utilising the battery are computed based on the per unit interest rates as per Appendix 2B[19]

4.3 Transmission and Distribution

Open Access (OA) is an approach to providing unrestricted access to the electricity transmission and distribution system. This approach has been envisaged in the Electricity Act, 2003 (EA 2003) as a framework to encourage competition in the electricity sector and to enable consumers to choose their suppliers. Open access also helps ease the power shortage since several power producers can now transmit power from their generation plants to different load centres.

Consumers and generators can mutually decide to come together to source electricity using transmission and distribution networks, provided they pay the required charges to the respective entities. The key applicable open access charges are –Transmission Charges, Transmission Loss Compensation, Wheeling Charges, Wheeling Loss Compensation, and Additional surcharges, which amount to ₹0.98/ kWh as displayed in Table 4.3.1

TANGEDCO T&D Charges	
Grid Charges	Basic Value (₹/ kWh)
Wheeling charges	0.47
Transmission Charges	0.39
Self-Generation Tax	0.10
Meter Reading Charges	0.00
Scheduling Charges	0.01
System Operating Charges	0.00
Reactive Power Charges	0.01
Other	0.00
Total Grid Charges (₹/ kWh)	**0.98**

Table. 4.3.1: TANGEDCO T&D Charges

[19] Appendix 2B - Effective Cost of Battery Usage

4.4. Losses Involved

There are two components which contribute to Grid losses:

Transmission Losses: Transmitting electricity at high voltage leads to a fraction of energy lost due to heating, which varies by conductor type, the current, and the transmission distance.

Wheeling / Distribution Losses: The major number of losses in a power system is in primary and secondary distribution lines. Factors contributing to these losses may be due to inadequate conductor sizes, lengthy distribution lines, introducing distribution transformers away from load centres and so on.

Grid Losses	
Transmission Losses (%)	2.34%
Wheeling/Distribution Losses (%)	0.72%
Total Losses	**3.06%**

Table. 4.3.1: Factors contributing Grid Losses (Tamil Nadu)

These losses differ based on the capacity of the transformer, the injected and withdrawn voltage, and totals up to 3.06% as displayed in Table 4.3.1 for IITMRP in Tamil Nadu.

4.5. Cost Benefit Analysis of the proposed RE scenario

The data and analysis presented so far in this report detail all the elements required to compute the total cost of electricity in two different scenarios. The first scenario is when we obtain electricity from the current[20] utility provider to IITMRP. Note that the electricity provided is primarily form thermal power-plants[21]. The second scenario is where IITMRP procures electricity from wind and solar plants, contracted under the group-captive mechanism. The generated electricity is instantly[22] wheeled in to IITMRP through the existing transmission and distribution network of the utility. IITMRP will use the electricity wheeled in and stores all excess energy in its local energy storage systems. If the generated and wheeled in energy falls short of the demand at any time, the required deficit is met by the local storage systems. All cost heads are derived based on prevailing tariff orders from Tamil Nadu and competitive rates sourced from the market in mid-2023. Based on the data collected from the Research Park, the per unit cost for each category is then computed to arrive at the all-inclusive total landed cost of electricity. For any investment required in second scenario (for local storage systems as well the amount paid for setting up

[20] Tamil Nadu Electricity Board (TNEB)
[21] As mentioned in section 4.5, Indian power grid today gets 54% of electricity from thermal and other fossil-fuel based plants and 31% from renewables (including solar, wind, biomass, hydro and atomic energy) as per 2023 data
[22] It is assumed in the analysis that the utility will not store any of the renewable energy generated by the contracted group-captive plants and the electricity generated will be fully transported instantly to IITMRP to manage.

captive solar and wind plants), the corresponding depreciation, finance cost (at 10%) and operation and maintenance cost is included in computation.

A comparative picture of the current scenario, which is primarily grid-based electricity coming from TNEB in this case, and a proposed RE scenario with around a 90% share of electricity through captive Solar and Wind plants plus local storage and 10% requirement coming from the grid is presented in Table 4.4.1. The table highlights the economics of each scenario.

Average Monthly Cost of Energy for a Commercial Complex in 2022		
	Current Scenario	Proposed Scenario with 90% RE
Particulars	Units (kWh)	
Solar (wheeled-in)	-	5,81,250
Wind (wheeled-in)	-	5,41,437
Commercial	12,73,790	1,60,108
Diesel Generator	18,011	9005
Total	**12,91,801**	**12,91,801**
Particulars	Per unit rates (₹/ kWh)	
Solar (wheeled-in)	-	4.57
Wind (wheeled-in)	-	4.52
Commercial	8.70	8.70
Diesel Generator	31.33	31.33
Storage (Assuming 30% RE)	-	2.67
Particulars	Overall average rates (₹/ kWh)	
Consumption charges/unit	8.70	7.38
Peak Hour Consumption Cost/unit	0.64	0.48
Demand charges/unit	2.08	1.62
Tax, meter rent/unit	0.57	0.16
Avg rate without DG	**11.99**	**9.63**
Avg rate with DG	**12.31**	**9.80**
Average Monthly Cost	₹ 1,58,12,804	₹ 1,25,23,887
Estimated Monthly Savings (₹)		**₹ 32,88,917**

Table. 4.4.1: Cost comparison between current and future scenario for a commercial complex

The cost per kWh of electricity in Scenario I (electricity obtained fully from local utility and use of DG when needed) is ₹12.31 per kWh. In Scenario II, the average cost of electricity turns out to be only ₹9.80 per kWh. This implies that with 90% electricity coming from captive solar and wind plants and the required local storage, there is a net saving of ₹2.51 per kWh as shown Table 4.1.1. This would amount to a total monthly savings of ₹32,88,917 for IITMRP.

The result is remarkable. Instead of using the electricity from the DISCOM, which is dominantly fossil fuel based, moving to 90% RE saves money for IITMRP. The technologies used are innovative but also available today. Moreover, the study would be valid for almost any commercial complex in India today. What would then be the reason for such commercial complexes to not switch-over to such an approach and use mostly green electricity? The combination of moving to green electricity and saving costs is indeed hard to believe, but true. The only reasons for this to not happen could be due to:

i. lack of knowledge in this regard or
ii. unavailability of some of the sub-systems required for this change.

This report aims to bridge the lack of knowledge gap.

Having presented this detailed analysis, we do one more exercise. Considering today's costs, what would be the time taken to get a positive Return on Investment (ROI). Solar, Wind and Energy storage systems offer a ready means to fully transition towards RE based systems. The total investments to take IITMRP on Renewables and Storage sums up to ₹21,53,78,248 as detailed in Table 4.4.2. Based on the computed estimated yearly savings of ₹3,94,67,008 from utilizing RE based systems bring the RoI to only 5.5 years. It is important to note that the investments made are for a much longer period (Solar and wind being for 20 to 25 years), making this a remarkable feat indeed.

Systems Considered	Group captive investment for RE (₹)
Solar – 2 MW	64,00,000
Solar with trackers – 2 MW	90,00,000
Wind – 2 MW	2,73,00,000
Battery – 8 MWh	15,26,78,248
Thermal Storage	2,00,00,000
Total investment	**₹ 21,53,78,248**
Savings per year	**₹ 3,94,67,008**
ROI (years)	**5.5**

Table. 4.4.2: Return on Investment Computation for Renewables and Storage

5.Summary, Conclusion, and way forward

Today in Chennai, the total all-inclusive cost of electricity for a commercial complex (based on TNEB grid-based electricity rate and usage of DG when needed) amounts to ₹12.31 per unit. On the other hand, systems enabling use of RE to almost 90%, as highlighted in this paper, offer cost-savings for a commercial complex. The generation cost of electricity from solar and wind stands around ₹3.00 - ₹4.00 based on prevailing market rates; with the inclusion of applicable transmission and distribution charges as well as losses incurred, the total landed cost of solar and wind to the consumer still falls under ₹5.00. The addition of storage to add the much-needed flexibility to enable 24*7 RE power comes at a computed additional cost of ₹2.67 per kWh. This includes the finance costs and depreciation on capital deployed towards it. As storage is a critical component towards enabling renewable energy throughout the day, we have estimated the storage size for a campus like the IITM Research Park to be of the order of 8 MWh. Further, this also plays a key role of optimizing the Demand Charges. The cost savings by attaining a 90% share of renewables totals up to ₹2.51 per unit, which translates to approximately ₹32,88,917 per month. The total yearly expenditure on electricity for such a commercial complex from the local utility grid amounts to ₹18,97,53,647. Following investments in setting up solar, wind, storage, and an energy management system we see that one can bring down the expenditure incurred on electricity by up to 30%, resulting in an annual savings of ₹3,94,67,008 for the Research Park.

The Commercial and Industrial sector are today some of the most energy intensive consumers of electricity in the country. Electricity usage and its rates are also increasing rapidly, with data showing that commercial sector in particular pay on average 40% higher than other categories of consumers. The conclusion will be equally valid for the High-Income Group (HIG) Housing. The HIG consumers today pay high rates for electricity (based on the high number of units consumed per month) and could easily benefit by such an approach. The resounding call for change rings loudest in the commercial category for the same reasons, given the financial edge that RE based systems now offer.

Today, moving towards RE powered complexes is no longer a distant possibility as the technologies required and elaborated in this report are ready to be deployed at scale. As India's GDP grows, it would build very significantly; it is believed that over the next twenty years, India may build twice as much as it has today. This rapid increase in the building sector signals a huge growth opportunity for commercial and HIG residential buildings to adopt renewables. Coupled with the increasing grid tariffs and push towards sustainable growth, the timing seems apt to embark on this breakthrough towards this green transition. By undertaking the approach showcased by IITMRP towards renewables, commercial buildings across the country can take a significant leap towards renewables whilst also reducing its overall monthly electricity expenses. The Return on Investment in renewables and storage can be obtained within a 5-year period. At a time when businesses, investors and customers across the board are becoming increasingly aware of the rising threats of GHG emissions and climate change, the economic opportunity makes it an imperative choice towards enabling an environmentally friendly and financial prudent future. As a long-term goal, this approach would help increase the renewable energy share in the country and ensure significant reduction in overall carbon emissions whilst also reducing costs for the end-consumer. Given the government's ambition to grow India's renewable capacity and usage, this approach will be a great stepping-stone towards a greener future not only for commercial complexes but could soon also be replicated in industrial and residential settings across the country.

Appendix

Appendix 1: Demand Load Factor (DLF)

TNEB has a fixed and rather high monthly charge based on Maximum Demand (MD) contracted by the consumer. Penalty for exceeding MD is very high and may also result in disconnection. The user draws from the grid various amounts of electricity throughout the day and night. The current MD in Chennai would amount to barely ₹0.78 per kWh if the consumer draws uniform power from the grid equal to MD. But a user draws only as per his/her demand which for the Research Park amounts to ₹11,50,976 based on average per minute consumption. The result is quite a high effective add on MD Charges per kWh.

Strategy:

A strategy to increase DLF % and thereby reduce MD Charges per kWh is to have ***local energy storage*** and draw power uniformly. If the storage reduces the MD as 3000 kVA the MD charges per kWh would have come up to ₹0.78/ kWh as per current demand. Another factor which plays a role in MD/ kWh is the Power Factor (PF) as maximum demand is not as per kWh consumed but is based on kVA drawn. So, in IITMRP the current DLF% is calculated. as follows:

Table 1.1 Summary of IITMRP's Demand Charges

Particular	Value	Unit
Demand Charge	562	₹/kVA
Total Sanctioned Demand	5000	kVA
Total Demand Charges (Fixed)	28,10,000	₹
Cost per kWh (With full utilization)	0.78	₹/ kVA
Single maximum peak demand recorded - 2022	4687	kVA
IITMRP Average Per minute Demand - 2022	2048	kVA
IITMRP Utilization of maximum sanctioned demand	**41%**	**%**

Table 1.2 Cost per kWh assuming a flat demand as per DLF%

Demand Load Factor	Cost per kWh assuming a flat demand (₹)
30%	2.60
50%	1.56
75%	1.04
100%	0.78

Table 1.3 Average Hour wise demand recorded between June'22 - June'23	
Hour	Hour wise demand recorded (kVA)
0	1611
1	1580
2	1497
3	1467
4	1438
5	1458
6	1528
7	1746
8	2069
9	2409
10	2571
11	2597
12	2580
13	2561
14	2656
15	2702
16	2766
17	2763
18	2446
19	2054
20	1821
21	1703
22	1617
23	1562
Average Demand (kVA)	**2050**

Appendix 2A: Capital Cost of Lithium-Ion Battery Storage

Battery is a capital cost. Depending upon its capacity in kWh it has a certain number of charge/ discharge cycles based on the battery chemistry. Further battery capacity itself deteriorates over time and will not be useful beyond a certain limit depending on application. For an EV battery, replacement is required when its capacity becomes 80% of original capacity whereas for a fixed storage one may be able to use a battery up to 50% of its capacity. The battery after reaching its useful life may have scrap value.

Thus, multiple parameters need to compute effective cost of usage of battery/kWh:

1. Total Capital cost of battery.
2. End of Life %: is defined in terms of number of charge & discharge cycles served by the battery before it is scrapped- which gives the depreciation value.
Note: the battery life cycle will depend on battery capacity and its End of Life.
3. Interest cost
4. No. of average charge/discharge cycles used per day.
5. Rate of deterioration of battery life- here we will assume linear deterioration from full capacity to capacity value at end of life.
6. Percentage of battery Capacity used per cycle. The battery cannot be fully charged or discharged. Typically for a storage battery we can use 90% capacity.

From this we compute the following:

a) Usable Battery Capacity = (Depth of Discharge %)* (1+ End of Life %)/ 2
b) No of years of battery life cycle = Battery cycles / (365* No of charge or discharge cycles per day)
c) Battery cost per kWh = -PMT(Interest rate, Battery Life in years, Battery cost per kWh)

A battery consists of the following components:

Assuming: 5600 number of cells for 1MWh battery capacity

a) Manufactured battery:
- Cell Cost including insurance and transport charges
- BMS Hardware and Mechanics for the battery

b) Converter Cost

c) Miscellaneous Charges including Container, Ventilator and Safety and Fire protection charges

Table 2.1 Capital Cost for 1 MWh Pilot Battery		
A. Manufactured Battery Cost		
Particular	Value	Percentage
Cost per Cell (Rs.)	₹ 3,361	
Total Cell cost for 1MWh	₹ 1,88,20,900	56%
Miscellaneous Charges (including insurance, tax, transport and duty charges)	₹ 49,71,112	15%
BMS Hardware	₹ 6,00,000	2%
Mechanics	₹ 58,47,551	17%
B. Converter Cost		
Particular	Value	Percentage
Converter Cost	₹ 18,70,000	5%
C. Miscellaneous Charges		
Container Cost	₹ 4,80,000	1%
Ventilation Cost	₹ 2,50,000	1%
Additional Cost for safety and fire protection	₹ 8,00,000	2%
Cable Cost and accessories	₹ 15,00,000	4%
Total Cost for 1MWh Pilot Battery excluding Capital and Operations Cost	**₹ 3,51,39,563**	
Total Cost for 1MWh Battery after Commercialization	**₹ 1,90,84,781**	

Table 2.2 Battery Cost per kWh after commercialization (₹/kWh)	
Particular	**Value**
Capital Cost (per kWh)	₹ 19,085
Usable Life cycles	10000
Average Capacity Utilization	50%
Interest Rate %	10%
Charge-discharge cycles used per day	1.5
Depth of Discharge %	90%
End of Life %	50%
Usable Battery Capacity kWh	0.675
Battery Life in years	9
Battery Cost per year	₹ 3,284
Battery Cost per kWh (₹/kWh)	₹ 8.89

Appendix 2B: Effective Cost of Battery Usage

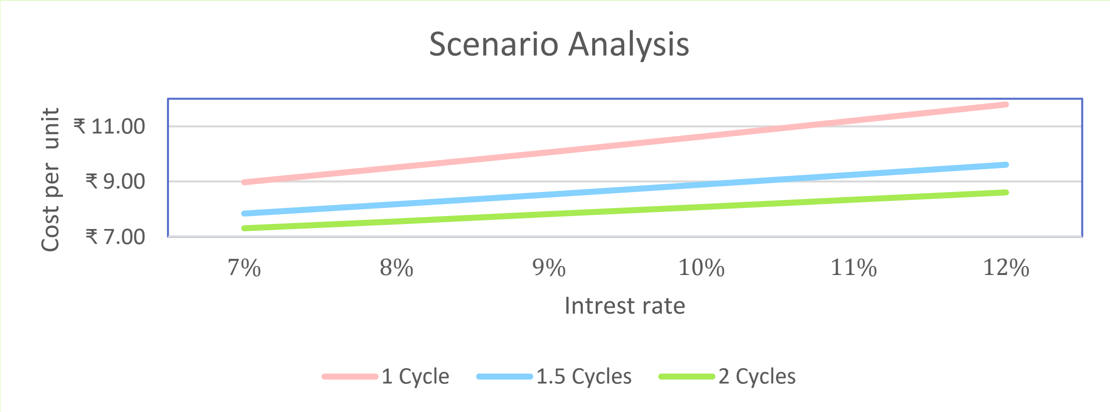
The capital cost of the battery is calculated assuming a 10% interest rate considering 1.5 charge/discharge cycles. But the cost /kWh of battery will vary based on number of cycles used in a day and the interest rate considered.

The following parameters are calculated as follows:

i. Interest Cost over Life of battery: [(Battery Cost per year * Battery life in years) – Battery Cost] / Battery life in years

ii. Depreciation = (Battery Cost per year - Interest Cost over Life of battery)

Interest Rate (%) / Number of cycles per day	**7%**	**8%**	**9%**	**10%**	**11%**	**12%**
1 Cycle	₹ 8.97	₹ 9.51	₹ 10.06	₹ 10.63	₹ 11.20	₹ 11.79
1.5 Cycles	₹ 7.84	₹ 8.18	₹ 8.53	₹ 8.89	₹ 9.25	₹ 9.61
2 Cycles	₹ 7.31	₹ 7.56	₹ 7.82	₹ 8.08	₹ 8.34	₹ 8.61



	1 Cycle					
Battery Cost	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085
Usable life cycles	10000	10000	10000	10000	10000	10000
Average Capacity Utilization	50%	50%	50%	50%	50%	50%
Interest Rate %	7%	8%	9%	10%	11%	12%
Charge-discharge cycles used per day	1	1	1	1	1	1
Depth of Discharge %	90%	90%	90%	90%	90%	90%
End of Life %	50%	50%	50%	50%	50%	50%
Usable Battery Capacity kWh	0.675	0.675	0.675	0.675	0.675	0.675
Battery Life in years	14	14	14	14	14	14
Battery Cost per year	₹ 2,211	₹ 2,343	₹ 2,479	₹ 2,618	₹ 2,760	₹ 2,905
Battery Cost per kWh (₹/kWh)	₹ 8.97	₹ 9.51	₹ 10.06	₹ 10.63	₹ 11.20	₹ 11.79

	1.5 Cycles					
Battery Cost	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085
Usable life cycles	10000	10000	10000	10000	10000	10000
Average Capacity Utilization	50%	50%	50%	50%	50%	50%
Interest Rate %	**7%**	**8%**	**9%**	**10%**	**11%**	**12%**
Charge-discharge cycles used per day	1.5	1.5	1.5	1.5	1.5	1.5
Depth of Discharge %	90%	90%	90%	90%	90%	90%
End of Life %	50%	50%	50%	50%	50%	50%
Usable Battery Capacity kWh	0.675	0.675	0.675	0.675	0.675	0.675
Battery Life in years	9	9	9	9	9	9
Battery Cost per year	₹ 2,898	₹ 3,024	₹ 3,153	₹ 3,284	₹ 3,417	₹ 3,552
Battery Cost per kWh (₹/kWh)	₹ 7.84	₹ 8.18	₹ 8.53	₹ 8.89	₹ 9.25	₹ 9.61

	2 Cycles					
Battery Cost	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085	₹ 19,085
Usable life cycles	10000	10000	10000	10000	10000	10000
Average Capacity Utilization	50%	50%	50%	50%	50%	50%
Interest Rate %	**7%**	**8%**	**9%**	**10%**	**11%**	**12%**
Charge-discharge cycles used per day	2	2	2	2	2	2
Depth of Discharge %	90%	90%	90%	90%	90%	90%
End of Life %	50%	50%	50%	50%	50%	50%
Usable Battery Capacity kWh	0.675	0.675	0.675	0.675	0.675	0.675
Battery Life in years	7	7	7	7	7	7
Battery Cost per year	₹ 3,602	₹ 3,727	₹ 3,853	₹ 3,981	₹ 4,111	₹ 4,242
Battery Cost per kWh (₹/kWh)	₹ 7.31	₹ 7.56	₹ 7.82	₹ 8.08	₹ 8.34	₹ 8.61

APPENDIX 3- Percentage of RE Going into Storage

Appendix 3 contains the percentage of Renewable Energy (2MW of wind, 2MW of wheeled in solar and 2MW of wheeled in solar with trackers and 1MW of rooftop solar) going into storage based on a 10% increase to the actual load of 2022 within a 15-minute time interval.

Definitions / Assumptions made:

1. The Current load and Total RE Generated are plotted for a 15-minute time interval for an average day in each month
2. Current Load (kWh) + 10% Increase: *A typical day per month is taken by considering a 10% increase to the actual load of a month in 2022.*
3. Total RE Generated (kWh): A typical generation per day of month is computed based on contracted capacity and existing rooftop generation
4. Assuming storage is available whenever RE supply exceeds demand in any 15 minutes of the day and energy can be drawn from storage during deficit on a typical weekday or weekend of every month.

TABLE 3.1 Weekday (Monday - Friday)

Month	Current Load (kWh) + 10% Increase	Total RE Generated (kWh)	Peak Storage capacity (kWh) requirement over a 15-minute energy settlement	Share of RE
January	44281	33398	2912	75%
February	57540	37087	116	64%
March	48935	28562	1672	58%
April	52343	27664	1351	53%
May	54049	40529	1509	75%
June	57184	56941	4879	100%
July	55942	55576	4721	99%
August	54156	53979	5270	100%
September	56825	41711	530	73%
October	55098	30027	206	54%
November	53567	25509	0	48%
December	53954	35087	382	65%

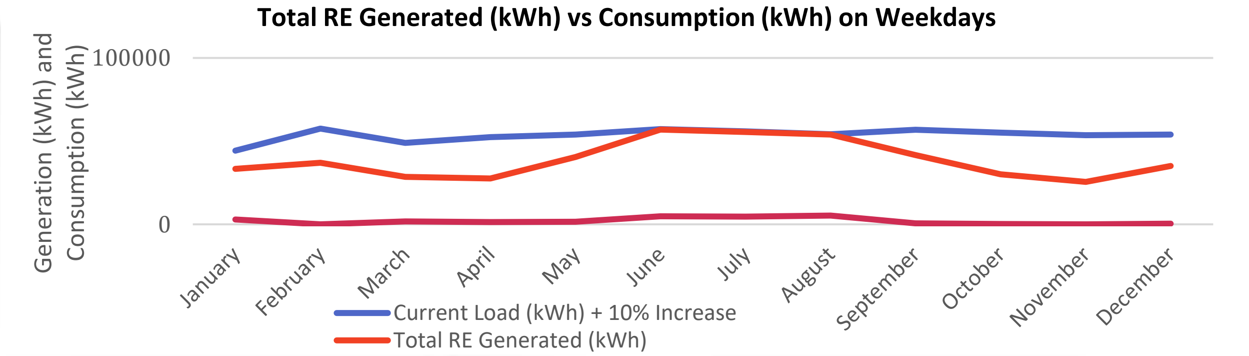


TABLE 3.2 Weekend (Saturday + Sunday)

Month	Current Load (kWh) + 10% Increase	Total RE Generated (kWh)	Peak Storage capacity (kWh) requirement over a 15-minute energy settlement	Share of RE
January	32546	31052	6901	95%
February	46152	42092	9841	91%
March	35607	29582	9707	83%
April	37849	27880	7014	74%
May	38272	36251	8486	95%
June	40137	58707	**18507**	146%
July	37643	52469	**14922**	139%
August	36052	50976	**16666**	141%
September	37431	48918	**15356**	131%
October	42089	29602	5549	70%
November	38136	26171	5266	69%
December	47080	36668	3422	78%

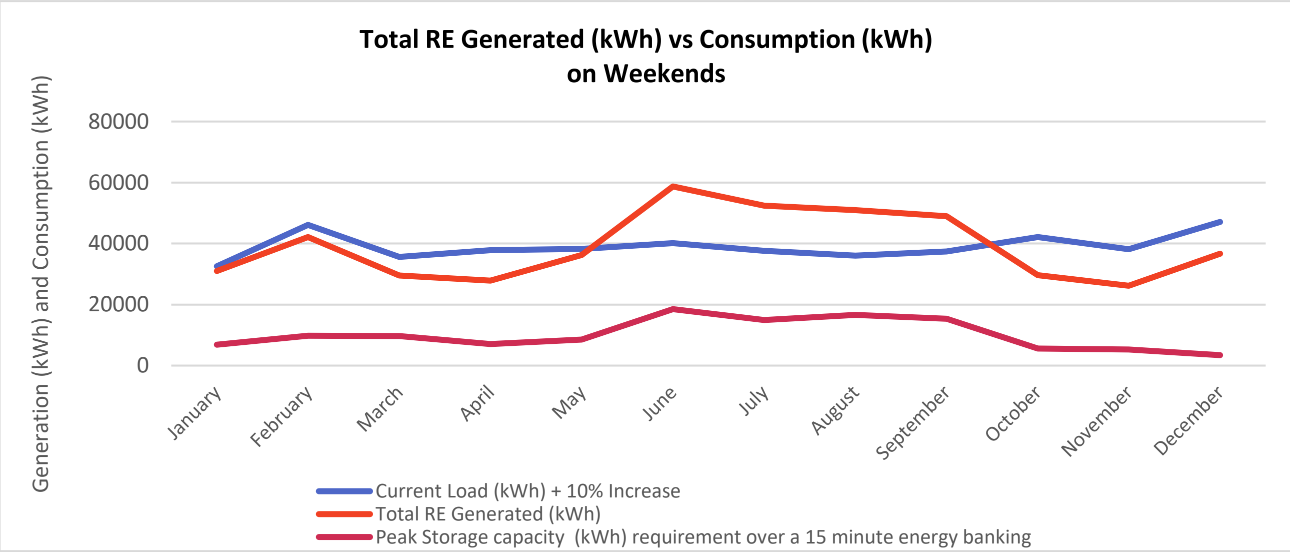
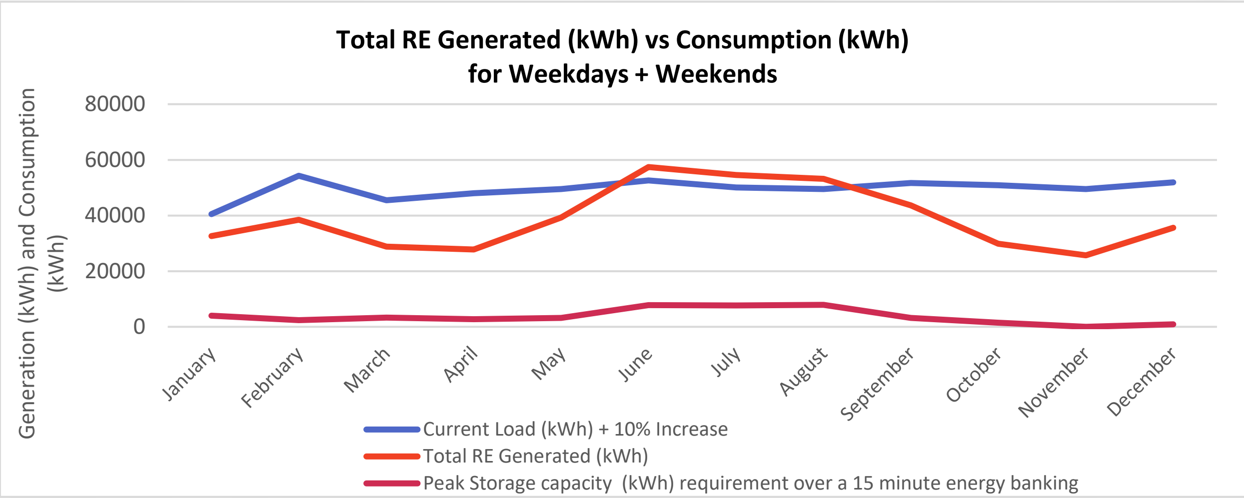


TABLE 3.3 All Day (Weekend + Weekday)				
Month	Current Load (kWh) + 10% Increase	Total RE Generated (kWh)	Peak Storage capacity (kWh) requirement over a 15-minute energy settlement	Share of RE
January	40495	32642	4017	81%
February	54286	38517	2386	71%
March	45496	28825	3324	63%
April	47995	27729	2776	58%
May	49469	39287	3203	79%
June	52638	57412	**7813**	109%
July	50039	54574	**7665**	109%
August	49484	53204	**7898**	108%
September	51654	43633	3250	84%
October	50902	29890	1492	59%
November	49452	25685	9	52%
December	51957	35544	878	68%



For the current load one will require long term storage during on all days between June- September. Whereas for the above computations by considering a 10% increase to the current load we will require a long-term storage system in *weekends* during the months of June, July, August, and September.
Assuming that weekday excess is handled by short term storage and the excess energy during consecutive holidays and on weekends can be handled by long term storage we can estimate a peak storage value of **7898 kWh for all days of the week** and **18507 kWh during weekends.**

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