ASSESSING CLEAN ENERGY OPPORTUNITIES THROUGH DEMAND AGGREGATION IN BENGALURU'S APARTMENT BUILDINGS

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EXECUTIVE SUMMARY

Highlights

- Buildings and construction sector are one of the largest sources of carbon emissions, and residential buildings alone account for 22 percent of global energy use and 17 percent of energy-related carbon dioxide emissions (IEA and UNEP 2018). Cities cannot take serious action on climate without prioritizing residential buildings. The combination of energy efficiency (EE) measures and on- or off-site renewable energy (RE) is a powerful tool for tackling building-related emissions.
- In India, the information technology hub of Bengaluru has experienced rapid inward migration from highly skilled Indian professionals. Apartment buildings are quickly emerging as housing choices in this land-constrained city. To meet the service expectations of people and to offer increasingly attractive housing options, developers are providing water, power, safety, and exclusive access to premium amenities through private gated residential apartment complexes. There are significant energy-consumption implications built into the provision and maintenance of these common area facilities by apartment complexes.
- The apartment owners associations (AOA), as a single collective group of residents in each complex, makes decisions on the management of common area facilities. Engaging with AOAs alone may ensure efficiency in services and on-site rooftop solar (RTS) wherever feasible, to meet energy needs. We consider apartment complexes as natural aggregators of energy demand and AOAs as potential partners to accelerate clean energy interventions in apartment complexes.

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.

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- We engaged with 10 apartment complexes in Bengaluru to assess their common area energy use to identify potential EE measures and the feasibility of RTS in the complexes. Post-assessment, we were able to recommend implementation of clean energy interventions to the complexes.
- While apartment complexes showed an interest in undertaking the recommended interventions, we found that there were institutional, management, and policy barriers to the adoption of these interventions.
- Using demand aggregation as a mechanism to promote clean energy pathways for residential apartment complexes will necessitate finding methods to overcome these barriers.

Background

India's building-sector trends in the global context

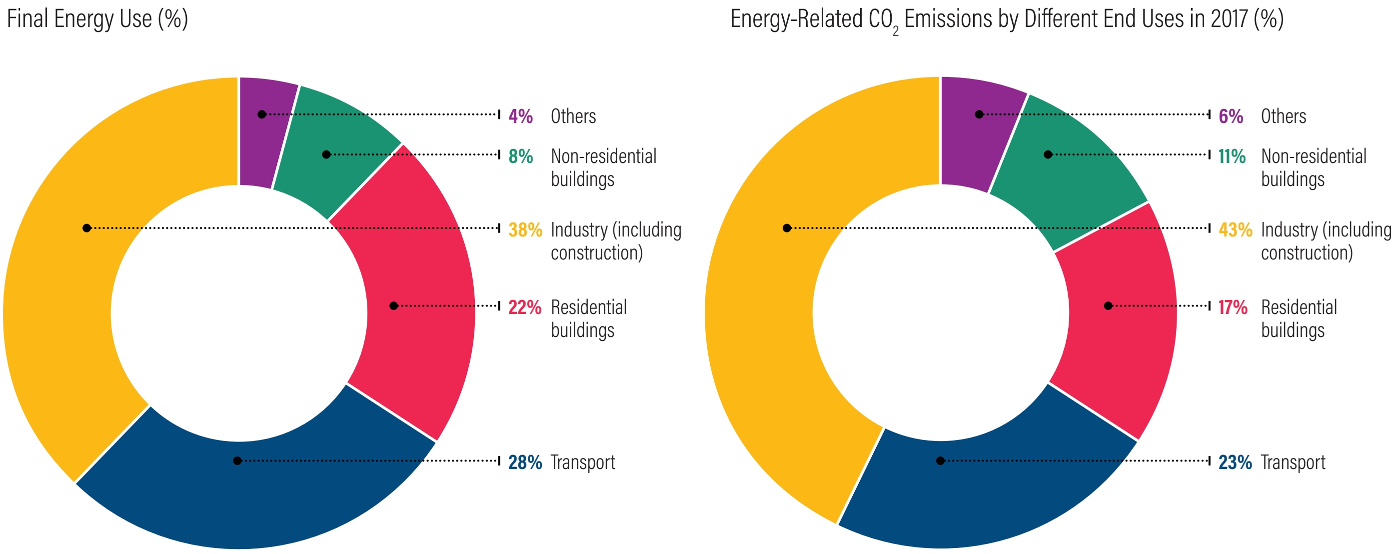
Buildings are now widely recognized as being among the worst offenders in man-made climate change. The numbers tell a story that demands attention and intervention. Globally, buildings accounted for 30 percent of final energy use.[1] Buildings also accounted for 28 percent of energy-related CO_2 emissions in 2017 (IEA and UNEP 2018). The residential buildings sector alone accounted for 22 percent of all building-sector emissions and 17 percent of energy-related CO_2 emissions worldwide (Figure ES-1). Global building-sector emissions have now been rising two years in a row (IEA 2018a). There was a marked decline in energy-intensity improvements in buildings from 2 percent in 2015 to 0.6 percent in 2018, while floor area coverage saw an increase of almost 2 percent between 2017 and 2018 (IEA 2018a).

After the African region, India is expected to be responsible for a large share of the global new-building stock between 2030 and 2050 (IEA and UNEP 2018). Projections estimate that building stock in fast-urbanizing India, will reach 31.5 billion m² by 2037 from 16.4 billion m² in 2017 (AEEE 2018) (Figure ES-2). Under a business-as-usual (BAU) scenario, global change assessment models predict a threefold increase in final energy consumption in Indian cities between 2020 and 2050, largely driven by the demand for cooling and heating in buildings (Chaturvedi et al. 2014). In fact, globally, the fastest rate of growth in energy consumption by buildings through 2040 will occur in India (USEIA 2017). These alarming trends, juxtaposed against a projected doubling of global building stock by 2060, have created an urgent need for decarbonization of the buildings sector and for the decoupling of building-stock growth and emissions.

India's residential buildings: opportunities for clean energy transition

Residential buildings accounted for 24 percent of the total electricity consumption in India in 2018, a consumption that is growing at a Compounded Annual Growth Rate (CAGR) of 7.9 percent, second only to industrial-sector electricity consumption (MOSPI 2018).

Figure ES-1 | **Final Energy Use and Energy-Related CO_2 Emissions by Different End Uses in 2017 (%)**



Source: Data from IEA and UNEP (2018).

Figure ES-2 | **Projections for Building-Stock Growth in India**

Source: Data from AEEE (2018).

The residential building stock in India is projected to reach 28.4 billion m² by 2037 from 15.3 billion m² in 2017 (AEEE 2018). Spurred by increased urbanization, a rise in incomes and standard of living, and increased access to electricity, residential building stock is set to crest to almost double in two decades. This increase will most certainly have critical consequences for India's energy security and its control on emissions, especially if new buildings do not accelerate the pace of integration of EE and RE generation.

National policies to promote both EE and RE in the residential buildings sector in India have seen significant progress in the last decade. India's 100 gigawatt solar energy target includes a 40 gigawatt target to be achieved through grid-connected RTS by residential and institutional consumers (Niti Aayog 2015). In parallel, building codes and energy performance standards for energy-intensive appliances and equipment have been upgraded. The first part of the code for residential buildings, Eco Niwas Samhita, was launched in 2018. Most recently, in April 2019, a labeling-cum-certification program for residential buildings was announced to accompany the roll-out of the code. For new residential buildings, codes and EE guidelines and on-site renewable generation must be implemented rapidly to meet India's commitments in its Nationally Determined Contribution of 33 to 35 percent reduction in emissions intensity of its gross domestic product (GDP) by 2030 and meeting Sustainable Development Goal targets.

The Bengaluru context: the trend toward more residential apartment buildings

The total final energy use in residential buildings is most affected by floor area and energy service activities. Understanding residential building typology trends and the demand for energy services in those typologies is critical for energy supply planning and has significant implications for India's efforts to transition to clean energy.

In major Indian cities, both city-center densification and urban sprawls are characterized by multistoried apartment complexes meeting the housing needs of a fast-growing population. While there is no public data set to support this trend, the visibly changing skyline of Bengaluru clearly highlights a growing trend toward apartment complexes as preferred residential housing solutions. While this type of residential development has worked for several cities internationally, the lack of emphasis on planning infrastructure in Bengaluru and other Indian cities negates the benefits that might accrue from accommodating more people on smaller land parcels. Multistoried apartment complexes have a larger floor area than detached or independent houses. The energy-use implications of this growth in floor space must be investigated, given the emphasis on higher floor space indices in many Indian cities (MOHUA 2017).

Apartment complexes in Bengaluru tend to comprise a gated cluster of one or more apartment buildings. These gated communities, as they are commonly referred to in public discourse in the city, represent the types of facilities (open spaces, leisure amenities) and infrastructure (24/7 water and electricity supply, safety, and security) that should ideally be offered by the city's administration to all urban residents but are being privately provided by builders, most often at a huge cost to residents. Exclusive access to amenities like clubhouses, gymnasiums, and swimming pools adds to the attractiveness of these projects. The management of these common area facilities rests with AOAs.

The energy use in common services being shared and paid for by apartment residents can be significant, given that apartment complexes in Bengaluru can range from anywhere between 20 to more than 2,000 apartments with a proportional increase in the number of common amenities. Understanding the intensity of this aggregate energy use by residents can offer opportunities for deeper explorations of potential solutions for reducing this demand. The opportunities to curtail aggregate demand for common energy services from these buildings and to articulate clean energy pathways are also low-hanging fruit.

Apartment complexes as demand aggregators

We define aggregation as the act of grouping together multiple residents in an apartment complex as a single consumer of the services provided in a common area.

In apartment complexes, apartment residents share common areas that provide communal amenities.

As such, the energy used in common areas is the aggregate use from all residents for the services.

The case for demand aggregation to adopt clean energy measures and promote a low-carbon pathway

In 2014, WRI India attempted to aggregate energy demand from six corporate buyers to demonstrate combined RE procurement in one bid to achieve economies of scale and reduce transaction costs per project. The pilot concluded that the aggregation model worked best with companies within a small geographic area, such as an industrial or business park, and consisting of large and small buyers within a limited boundary. This study proved the case for demand aggregation and deemed anchor partners as being critical to drive successful implementation strategies. Aggregating demand in the residential sector has not been explored in India. A majority of the common area services like water pumping, elevators, lighting of indoor and outdoor common spaces and facilities like gymnasiums, clubhouses, and swimming pools are energy-dependent. Theoretically, for each service and facility, there exists a potential to introduce EE through higher efficiency equipment and appliances. It is also possible for entire energy loads of these common services and facilities to be met solely by RTS if the required roof space is available.

About This Working Paper

Possible clean energy pathways for the gated community residential development trend have not been studied yet. From June 2017 to December 2018, WRI India in partnership with Technology Informatics and Design Endeavor (TIDE) undertook research to understand energy used in common services of 10 existing apartment complexes in Bengaluru.

This paper examines the potential of clean energy interventions in existing apartment complexes serving as demand aggregators. The paper is based on primary data collected on common area energy use from each of the 10 apartment complexes we selected in Bengaluru. During this study we engaged intensively with the AOAs, EE and RTS vendors, and service providers. Our engagement with them was conducted through semi-structured interviews, participation in regular meetings, and interactions on different platforms. This study aimed to understand their perspectives and the barriers to implementing clean energy projects in apartment complexes.

The study we conducted was devised as a micro-model. Its findings are relevant for AOAs, apartment federations, EE and RTS vendors, and service providers. Power and water utilities and municipal bodies may also gain insights from this paper to tackle the challenges of rising energy use due to the growing number of apartment complexes in Bengaluru.

Our findings are based on analyses from 10 apartment complexes in Bengaluru. While we acknowledge that this study is not representative at a city level, we hope it can serve as a model for further research that will be required to draw meaningful correlations between the findings and the causative factors.

Research Objectives

Developing clean and efficient energy systems is key to India's climate change mitigation strategy. India's clean energy transition strategies comprise policies to promote both RE and energy efficiency. The motivating goal for our research was to understand and document the challenges to implementing demand aggregation for common area energy consumption in Bengaluru's apartment complexes and the benefits to be derived from implementing clean energy and RE interventions.

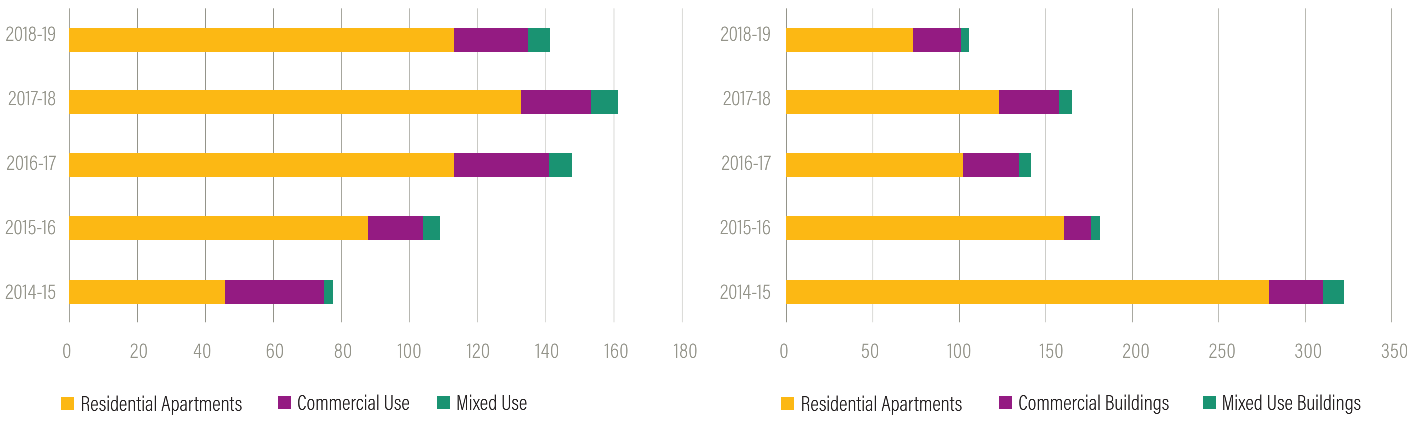
To put into perspective the significant pace of these developments and their implications in terms of energy use, between 2014 and 2019, in North and South Bengaluru alone, close to 500 apartment complexes (many of which are high-rises[2]) were handed occupancy certificates by the municipal corporation Bruhat Bengaluru Mahanagar Palike (BBMP)'s town and country planning office (Figure ES-3). Taking into account that this trend of high-rise apartment complexes is being mirrored in most major cities in India, we sought to assess the energy demand of these apartment complexes and evaluate the potential to make them partners in accelerating clean energy transition through demand aggregation.

In residential apartment complexes, the aggregation model may be considered under two scenarios:

Scenario 1: Aggregating energy demand for the common services of a cluster of apartment complexes in a neighborhood or a small geographic area, each complex managed by an individual AOA

Scenario 2: Aggregating energy demand for the common services of a single apartment complex managed by a single AOA

Figure ES-3 | **Occupancy Certificates Given (Left) and Building Plans Approved (Right) by BBMP North and South Joint Directorate of Town Planning, as of March 2019**



Source: Based on data from BBMP Town and Country Planning department, aggregated and analyzed by WRI authors.

For the purposes of this research study, we elected to examine scenario 2 in depth, as being the most relevant case for Bengaluru. Scenario 1 required participation from multiple apartment complexes within a neighborhood. During the course of the study, we realized that this was not easy to secure.

Our research objectives were as follows:

- Explore the potential for demand aggregation in 10 apartment complexes in Bengaluru by quantifying total energy use by common services, including electricity serving common end uses (lighting, water pumping, elevators, and miscellaneous equipment used in amenities like clubhouses, swimming pools, gymnasiums, and other areas specific to the apartment complex) and diesel use in power backup systems like diesel generators.
- Assess reduction in energy demand for common services through EE measures and the feasibility of meeting this demand through on-site RTS
- Assess potential cost savings as an incentive toward adopting clean energy and RTS interventions
- Recommend these clean energy interventions to apartment complexes and facilitate their implementation wherever possible
- Develop low-carbon pathways for common area energy use, based on different scenarios of EE, RTS, or both
- Document the perceptions of apartment residents, AOAs, EE and RE vendors, and service providers on the implementation of clean energy projects for common energy use in the 10 apartment buildings being assessed by this study

Findings and Critical Observations

WRI reviewed the energy consumption sources and devices in common areas of each of the 10 private developments selected for this study and looked for lessons and opportunities for future engagements around energy performance in this sector. We made the following observations:

- **Water pumping assets account for the largest share of total connected load in most apartment complexes.** The total connected common area electricity load for the 10 apartment complexes was four megawatts (excluding fire hydrant pumps). At an aggregate level, pumping assets alone accounted for 45 percent of the common area connected load of the 10 apartment complexes containing a total of 4,169 apartments. In six apartment complexes, pumping loads were more than 40 percent of the total common area connected load; and in others, pumping loads accounted for 15 to 28 percent of the total connected load.
- **In most apartment complexes, RTS can meet the entire annual electricity demand for common services.** Calculations based on available roof area showed that RTS could potentially meet all energy needs of the common areas for eight apartment complexes. For two other apartment complexes, due to roof space constraints, RTS could meet 25 to 50 percent of the common area energy needs. We also found that, despite solar water heaters being mandatory for apartment complexes as per BBMP bylaws of 2003, none of the apartment complexes had them.

- **There is a potential to devise and implement low-carbon pathways for reducing aggregate energy demand from the common services of apartment complexes.** Clean energy options comprising both EE and RTS measures, either individually or in combination, can be introduced in common areas of existing apartment complexes.
- **The energy savings potential technically possible in the 10 apartment complexes varies based on several factors:** The age of the building; its size and the size of the common areas; total occupancy; and the age, quality, efficiency, and maintenance of the equipment are the major factors that affect energy savings potential. To illustrate the variance range, in one of the apartment complexes, measures to save energy in water pumping and lighting could technically save 20 percent of electricity consumed in common areas. In some of the other complexes, lesser energy savings of up to 5 percent were possible.
- **Surrendering excess sanctioned load (or contracted power) can save apartments money.** In seven apartment complexes, the sanctioned load allocated on some utility meters was more than the maximum demand recorded. This reveals a potential opportunity for apartment complexes to surrender the excess sanctioned load, which can lead to significant savings on their electricity bills.
- **Surveyed AOAs lacked strong motivation to invest in EE and RTS measures**. As individual AOAs are the single entity managing common facilities in each complex, it is critical to secure their willingness to implement clean energy projects and interventions. When we interviewed AOA Management Committee (MC) members, we found that although the common area electricity bill is a concern to several AOAs, there are other budgetary items at a higher priority (such as water supply or waste management). In the state of Karnataka, subsidized domestic tariffs are levied on common area services that use electricity in Karnataka; hence, the incentive to invest in EE is low. Consequently, EE and RTS technology measures are not prioritized. Other barriers expressed by the AOA MC focused on the higher up-front investment required, reluctance to seek approvals from multiple decision-makers for changing the technologies used on site, and lack of access to publicly available and objective information on clean energy interventions. Interestingly, respondents view RTS as green or environmentally friendly, and MC members from six AOAs, expressed willingness to install RTS, despite technical constraints.
- **Data on energy use for common services is often not maintained or catalogued.** In all apartment complexes we studied, basic information on monthly or annual electricity bills was incomplete. Most AOAs were unaware of the number and the types of appliances, equipment, and other common area electrical assets owned or used by the complex and of the maintenance practices needed to operate these assets at effective functioning levels. Annual maintenance contracts (AMCs) are common for elevators but less common for diesel generators and completely absent for pumping systems. For the water pumping systems, maintenance is ad-hoc and effected when necessary through informal practices like motor rewinding that further degrade pump performance.[3]

Recommendations

Our study makes preliminary recommendations for clean energy procurement by apartment complexes. However, these recommendations will need to be substantiated by data and perspectives obtained from more apartment complexes in Bengaluru and other cities in order to be considered as specific and impactful intervention strategies. Certain broader recommendations could be conclusively arrived at and are listed as follows:

- **Promoting technology adoption through targeted interventions:** Programs that can aggregate demand for efficient products for a cluster of apartment complexes in the same neighborhood can be considered by organizations like Energy Efficiency Services Limited, a public-sector energy service company (ESCO). This is also true for RTS, a technology that can be implemented through collaborative procurement of solar (Thanikonda et al. 2015).
- **Enabling policies to encourage clean energy interventions:** There are currently no policy requirements for apartment complexes to conserve energy or to install RTS. Building bylaws can incorporate stronger mandates on use of energy-efficient equipment in new construction that goes beyond just energy-efficient lighting. Similarly, requirements on generating energy on site from RTS (as in the case of the state of Tamil Nadu) can be introduced. Market demand for these requirements can be created with more transparency being mandated from the developers. At a minimum, mandatory builders' self-declarations on life cycle costs of common assets could help consumers make informed choices.

- **Training and capacity building:** Given that ground personnel, operations staff, and supervisors, including electricians and plumbers employed by apartment complexes, are largely untrained or unskilled to run electrical assets optimally, programs covering improving the skills of these staff can be rolled out by state designated agencies (SDAs) in charge of EE and RE programs or utilities. For AOAs that want to pursue clean energy interventions but don't know where to start, good practice guides for management of common services can be helpful.
- **Compulsory maintenance of complete and comprehensive records by the AOAs:** Taking into account the coming into force of new codes and regulations and the move toward making compliance mandatory, the AOAs would be substantially supported in future compliance requirements by a shift toward maintaining detailed records on equipment and appliances, maintenance contracts and schedules, and energy consumption in the common areas of their respective complexes.

LIST OF ABBREVIATIONS

AMC:	Annual Maintenance Contract
AOA:	Apartment Owners Associations
BAU:	Business As Usual
BBMP:	Bruhat Bengaluru Mahanagara Palike
BEE:	Bureau of Energy Efficiency
BESCOM:	Bengaluru Electricity Supply Company
CFL:	Compact Fluorescent Lights
EE:	Energy Efficiency
ESCO:	Energy Service Company
KERC:	Karnataka Electricity Regulatory Commission
kW:	Kilowatt
LED:	Light-Emitting Diodes
MC:	Management Committee
MW:	Megawatts
RE:	Renewable Energy
RESCO:	Renewable Energy Service Company
RTS:	Rooftop Solar PV
SDA:	State Designated Agency
STP:	Sewage Treatment Plant
TFL:	Tubular Fluorescent Lamps

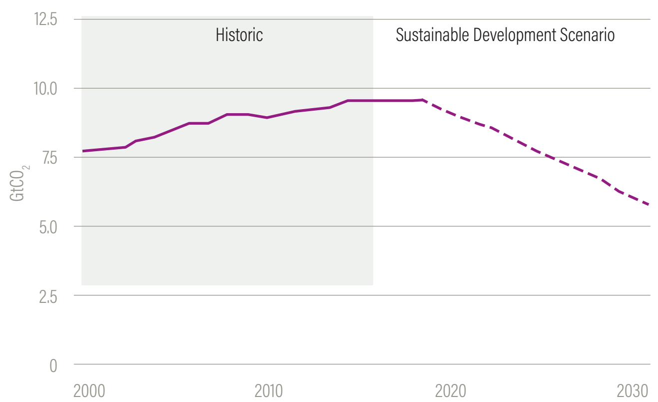
INTRODUCTION

Global Trends in Energy Use and Emissions by Buildings

Research has proved that buildings are the largest contributors to man-made climate change. While the overall share of buildings and the construction sector in global energy-related CO_2 emissions appears to have stabilized at roughly 28 percent since 2015, it is still the second-largest share of total global energy-related CO_2 emissions (IEA and UNEP 2018), a share that has been increasing for the last two years due to increase in floor area and activity levels, particularly in developing countries (IEA 2018a).

Since 2000, the shift toward EE improvements has demonstrated a positive impact through a decoupling of global floor area growth and energy demand (Figure 1) (IEA 2018b). Developing countries moving away from energy-intense traditional biomass and electrified end uses have also contributed to this decoupling.

Figure 1 | **Building-Sector CO_2 Emissions**



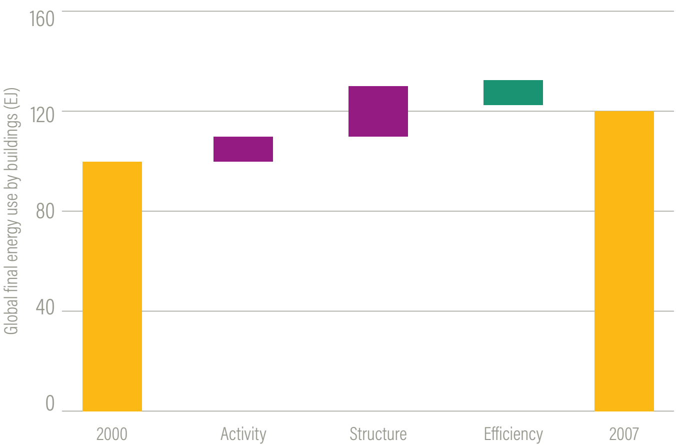
Source: IEA w2018a.

Despite the positive trends, energy intensity improvements in buildings are not happening quickly enough due to slow progress on high-impact policy instruments like building energy codes and certifications (IEA and UNEP 2018). Final energy use by buildings alone was 30 percent in 2017, three quarters of which came exclusively from residential buildings (IEA and UNEP 2018). This does not include energy used in construction of buildings (IEA and UNEP 2018). If energy efficiency improvements in buildings had not happened, final energy use in buildings could have been 12 percent higher in 2017 (IEA 2018b) (Figure 2).

It has become a matter of urgency to marshal all efforts to lend weight to the trend toward decoupling floor area growth and energy at the global, national, and local levels. This is because any positive impact of increased

EE in buildings can be quickly offset by growth in final energy demand from urbanization-driven building floor area increases, unless the buildings sector commits to carbon-free, renewable electricity. Integration of both components of the clean energy transition, EE and renewable generation, in new and existing buildings is therefore a climate-change mitigation imperative.

Figure 2 | **A Breakdown of Global Final Energy Use by Buildings, 2000–17, Showing the Decoupling of Energy Use from Economic Activity and Floor Area Growth Due to Efficiency Improvements**



Source: IEA 2018a.

The Role of Buildings in India's Clean Energy Transition: Mitigation Opportunities and Challenges

It is estimated that India's building sector can reduce global energy-related CO_2 emissions by 8 percent (Urge-Vorsatz et al. 2012). This can be achieved by deployment of building energy codes certifications, building capacity to implement these measures; and investing in good quality data on building stock and energy use, all of which will create sufficient conditions for investments in building efficiency (Graham and Rawal 2018). The challenge of buildings data is significant. In India, the completeness of top-down demand-side data on total building energy use provided through published government statistics is matched by limited or absent data on bottom-up estimates of building stock in cities, types and quantity of energy service uses, or end uses (e.g., lighting, cooling) and their general growth trends. This seriously hampers efforts to design and develop demand-side management programs and policies for the buildings sector. Most studies have relied on primary and secondary data, expert assumptions, and modeling to build a picture of India's total building footprint and its composition.

In 2018, a bottom-up approach to modeling India's building stock estimated residential building stock to be 15.3 billion m^2, projected to reach 28.4 billion m^2 by 2030 (AEEE 2018). India's residential buildings accounted for 24 percent of total electricity use, significantly higher than the consumption by commercial buildings (9 percent) (MOSPI 2018). As income levels rise and electricity becomes more reliable, residential electricity consumption is expected to increase manifold. National programs like the Prime Minister's Awas Yojana (colloquially referred to as 'housing for all by 2022') are also expected to drive up residential sector electricity consumption.

The twin pillars of India's transition to clean energy, EE and RE, have seen significant policy progress in the last decade since the launch of the Prime Ministers' Climate Change Action Plan in 2008. The two missions—National Solar Mission and National Mission on Enhanced Energy Efficiency—have resulted in the introduction of targeted schemes and programs. Given that all economic activities occur in buildings, their role and contribution to accelerating clean energy transition is critical to understand. The 40 GW RTS target set by the Government of India needs building rooftop space to be available for installation of RTS. The Bureau of Energy Efficiency (BEE)'s Energy Conservation Building Code (ECBC) 2017 for commercial buildings has already demonstrated its intention of integrating clean energy in buildings by prescribing requirements for on-site renewable generation in addition to the mandates on energy performance. The BEE has also introduced ECBC and a labeling program for residential buildings.

Clean Energy for Residential Apartment Complexes in Bengaluru

In this paper, we set out to examine the following crucial questions:

Can apartment complexes as single, contained units of energy demand be partners in the clean energy transition?

Can AOAs be the change agents for accelerating EE and RTS generation?

We assessed the energy demand from one specific type of residential building: high-rise apartment complexes that have a height of 15 meters and above (roughly ground floor plus four floors as per the BBMP definition, see Appendix A). While there are no open source datasets available on the typologies of residential buildings in Indian cities, there is a visible change in the skyline of Bengaluru that clearly highlights the growing trend toward multistoried apartment buildings.

A WRI India project, Building Sustainable, Energy-Efficient and Connected Communities in India, found that in Bengaluru, the rapid increase in population has led to a demand for housing that is being met by private developers in self-contained, large apartment complexes, referred to as integrated townships or gated communities (Sudhakaran et al. 2017). These high-rise residential apartment complexes have a significant resource footprint, and while public dialogue has tended to focus on visible and urgent issues like water and waste management, energy used in the common services shared by the apartments in each complex has been overlooked thus far. Individual AOAs are responsible for the running, administration, and maintenance of common facilities on behalf of all residents within their complex.

Apartment Complexes as Demand Aggregators

To understand these questions, we considered apartment complexes as natural aggregators where several residents share and use common services like water pumping, power backup, parking, hallways and lobbies, and elevators, as well as amenities like swimming pools, gymnasiums, indoor and outdoor recreation areas, etc. The common use of these and other facilities represent aggregated demand for these uses that otherwise would have been provided individually to each resident. The confined and bounded structure of an apartment complex managed and operated by AOAs offers the opportunity to improve efficiencies and promote clean energy to meet energy needs.

Study Objectives

Aggregating energy demand in the overall residential building sector in India and, more specifically, in the burgeoning apartment complexes has not been explored. To understand the size of this aggregate demand at the apartment complex scale, the study covered use of electricity and diesel (in diesel generators) in the provision of the common services at 10 apartment complexes in Bengaluru. We conducted semi-structured interviews with AOAs, vendors, and service providers to understand their perspectives on implementing EE and RTS projects in these buildings.

The study had the following objectives:

- Explore the potential for demand aggregation in 10 apartment complexes in Bengaluru by quantifying total energy use by common services, including electricity serving common end uses (lighting, water pumping, elevators and miscellaneous equipment used in amenities like clubhouses, swimming pools, gymnasiums, and other areas specific to the apartment complex) and diesel use in power backup systems like diesel generators
- Assess reduction in energy demand for common services through EE measures and the feasibility of meeting this demand through on-site RTS
- Assess potential cost savings as an incentive toward adopting clean energy and RTS interventions
- Recommend these clean energy interventions to apartment complexes and facilitate their implementation wherever possible
- Develop low-carbon pathways for common area energy use based on different scenarios of EE, RTS, or both
- Document the perceptions of apartment residents, AOAs, EE and RE vendors, and service providers on the implementation of clean energy projects for common energy use in the buildings being assessed by this study

We did not explore off-site RTS because, under the present regulatory scenario, it is not an option available to residential consumers.

Context for the Study

Bengaluru's apartment complexes and energy use

For Bengaluru's power distribution utility BESCOM, electricity consumption by the residential sector is increasing at the fastest rate, a CAGR of 7.13 percent between the financial years 2012–16, compared to commercial and industrial consumers at 2.36 percent and 1.52 percent CAGR respectively (BESCOM 2018).

Apartment complexes are not new to Bengaluru. The city began building apartment buildings in 1974, a three-story, cooperative society of 24 flats (Alva 2018). With time, the design of apartment buildings, the materials used, and the services provided have changed. Of the 10 apartment buildings we studied, 9 were constructed in the 2000s and only 1 96-unit apartment building was constructed in 1986. The single exception serves to reflect a change in consumer needs, aspirations, and the market response to those demands. For example, the older apartment building built in 1986 does not provide leisure amenities like clubhouses or gymnasiums, but the remaining nine apartment buildings have these, as well as swimming pools, tennis courts, saunas, and other attractive amenities.

Interventions driving clean energy implementation

National policies: In April 2019, BEE had introduced energy labeling requirements for residential buildings, applicable to single and multi-dwelling units but not covering common services in apartment complexes (BEE 2019). It is expected that the subsequent parts of the BEE's ECO Niwas Samhita (the Energy Conservation Building Code for residential buildings), due to be released in 2020 will prescribe provisions for EE in equipment, appliances, and amenities serving common services in residential buildings. Both the Indian Green Building Council (IGBC 2015) and Leadership in Energy and Environment Design have voluntary rating systems for apartment buildings. The former requires apartment buildings to install energy-efficient lighting, daylight sensors, BEE 3-star labeled equipment, and charging infrastructure for electric vehicles in common areas.

Local policies: In the state of Karnataka where Bengaluru is located, model building bylaws (Urban Development Department 2017a) require use of LED lighting in common areas and BEE star labeled appliances in all group housing projects, including apartment complexes, and a minimum 5 percent of connected load or 70 percent of the total roof size for RTS for group housing projects. Support for RTS is available from Karnataka Regulatory Commission (KERC)'s regulations and tariffs fixed for power generated from solar and rebates on solar water heater installation to BESCOM consumers (KERC 2016 and 2018). BBMP bylaws mandate solar water heaters in all buildings of a certain size and require solar PV-based common area lighting for multi-unit residential buildings (BBMP 2003). A description of policy and regulatory support for clean energy in apartment complexes in Bengaluru is given in Appendix B.

Existing initiatives on clean energy for apartment complexes: In 2014 and 2016, with the launch of two guidelines on the design of energy-efficient multistoried residential buildings for composite, hot-dry climates and warm-humid climates, respectively, the BEE indicated its intention to address, energy use in apartment buildings (BEE 2014, 2016). The guidance was based on data from one apartment building in Delhi with 90 flats in which elevators, lighting, and water pumping were found to consume 62 percent, 21 percent, and 17 percent of total electricity use, respectively. These guidelines represent the only published data on energy used in common services in apartment buildings in an Indian city. In addition to BEE's guidelines, the municipal corporation of Thane city in Maharashtra launched a technical guidebook on the implementation of clean energy projects in high-rise

Table 1 | **Possible EE Measures in Apartment Complexes**

COMMON AREA/UTILITY	ENERGY-SAVING MEASURES	SOURCES
Water Pumping	Correct sizing and choice of the pump, choice of more energy-efficient motors and auto controllers (water level-based on/off motors), designing pipes for maximum efficiency, and regular-scheduled maintenance	Shakti Foundation 2016
Lighting	Switching to lights with higher efficacies, such as LEDs, installation of sensors (motion, lux-based, or time-based) for more efficient operation	Curtis 2009
Elevators	Switching to more efficient motors, usage of control strategies (installing sensors or promoting behavioral changes, such as manually switching off fans/lights)	Shakti Foundation 2016
Diesel Generators (DGs)	BEE star labeled generators, better operation and maintenance practices, using alternatives like hybrid or solar DG sets	Shakti Foundation 2016; Kusakana and Vermaak 2014
Cool Roof Technology	Using a highly reflective surface (paint, sheet covering, tiles) for roofs of clubhouse to reflect sunlight	USDOE 2019
External Solar Shading	External solar shading for south, east, and west facing windows in clubhouses or party halls or other common areas to limit heating from the sun's rays	Shakti Foundation 2016

Source: WRI authors.

residential apartment buildings that described possible EE and RE interventions in common services like water pumping, lighting, and elevators. Table 1 describes possible EE measures in apartment complexes.

Solar technologies of choice for apartment complexes include solar PV for electricity generation and solar thermal for heated water in swimming pools and spa or sauna facilities. Other renewable technologies include waste-to-energy systems (Biogas) for electricity generation and heat pumps for heated water.

In Bengaluru and other Indian cities there are a few examples of EE and RTS projects for common services or the individual flats. These are given in Appendix C.

This working paper strives to document and assess the current data gaps in characterization of energy uses in common areas of apartment buildings and discuss how demand aggregation-enabled clean energy pathways can reduce emissions from the apartment complexes that were the focus of this study. Our findings are immediately relevant for the apartment owners or AOAs managing common area energy use in the 10 apartment complexes, as well as the providers of EE and RE products and services. Given the paucity of research studies on energy use in the common areas of residential apartment complexes, the wider relevance of the findings of this study could be significant for other AOAs in Bengaluru or apartment complex administrators in other cities, researchers, electricity utility providers, planners, and policy makers among others.

APPROACH AND METHODOLOGY

Defining Apartment Complexes

As per BBMP's building bylaws, a building with at least four apartments is considered an apartment building. A description of the definitions for common services by different agencies, acts, and rules is given in Appendix A. In public discourse in Bengaluru, the term *gated community* is often mentioned when referring to apartment complexes. Both BBMP and the Bangalore Development Authority do not legally recognize the term *gated community* and refer to such developments as *layouts*, a term defined by Karnataka's town and country planning department as "a subdivision of one or more plots held in one ownership or joint holders by laying out roads for the formation of building sites and earmarking area for park and open spaces, civic amenity sites, and public utilities" (Urban Development Department 2017b). Residential apartment buildings built on these layouts with common services, open spaces, and amenities exemplify apartment complexes.

In this study, we use *common services* as a collective term for the following features: pumping for domestic water use, waste water treatment, fire safety, and operating swimming pools; elevators; outdoor lighting on roads or streets and indoor lighting in passages, corridors, basements, stairwells, and equipment and appliances used in outdoor and indoor leisure and recreational areas (e.g., clubhouses); and power backup from diesel generator sets and any other amenity that serves all apartment occupants or resident maintenance staff and is administered, maintained, repaired, and paid for by all building residents either through monthly or annual monetary charges.

Identification of Apartment Complexes for the Study

In each apartment complex, the respective AOA is the sole authority that provides permission to collect data, conduct walk-through assessments, and perform energy audits. Therefore, gaining access to these buildings to gauge interest of the AOAs to participate in the study needed prior introductions either from the residents or the AOAs. Based on this limitation, we listed apartment complexes known to the study team or staff within WRII and TIDE. A preliminary list of 40 apartment complexes from all over Bengaluru was prepared considering criteria such as number of units, towers, or floors; age of construction; location or geographic spread of complexes; and the availability of a cluster of apartment complexes in a single neighborhood.

Appendix D provides a summary of the 10 apartment complexes selected for the study.

Methodology for Data Collection

Through our engagement with the 10 apartment complexes that were willing participate in the study and share data and information, we initiated a two-pronged methodology to meet our research objectives. First, we collected primary data on energy consumption by common services. The only other published data on common area energy use (BEE 2014, 2016) indicates that the top three users of energy are lighting, elevators, and water pumps. In Bangalore's context, given the high dependency on water pumping that we observed during our walk-through assessments and discussions with AOAs, we were keen to examine the efficiency of existing pumps and the possibilities of replacing energy-intensive units with efficient pump sets and exploring the option of aggregated procurement of efficient pumps. With these objectives in mind, we conducted energy audits of selected pumps, wherever it was feasible to do so. Secondly, we conducted semi-structured interviews with AOA MCs, EE and RTS vendors, and service providers in parallel with the primary data collection process. We participated in internal AOA MC meetings to discuss perceptions and obtain information relevant to the specific complex. We also engaged in several informal and formal interactions with the AOA team, supervisory staff, and maintenance personnel in the complexes.

The data for the 10 apartment complexes were collected between August 2017 and December 2018. After getting access to each complex, we consulted with a building supervisor or MC of the AOA to obtain information on the general profile of the complex. This information included year of construction of building or year of occupancy, number of flats or apartments, number of towers, annual or monthly maintenance budget, and percentage contribution of electricity or energy bill to the annual maintenance budget. Getting answers to the last two questions was difficult as some respondents could either give only best-guess estimates or were hesitant to share as they considered the information to be sensitive.

Energy in common services is consumed in the form of electricity that powers all electrical assets and equipment and diesel that powers the DG sets that function as backup power in case of outages. To build a complete picture of energy used in common services, we identified energy consumption data (electricity bills for all meters) and a list of electrical assets and equipment as being the most critical inputs.

Primary Data Collection on Baseline Energy Consumption

A template was prepared to collect data from an AOA MC or a building supervisor. Starting with an initial listing of core common services like lighting, pumping, and elevators that are common across all apartment buildings, we expanded our list of services and amenities that need energy, based on walk-through assessments and interactions with supervisors of the 10 apartment buildings. The final list of common services studied are given in Table 2. Most apartment complexes did not have all the data readily available and several data gaps were observed. To comprehensively capture energy used for all services, we made multiple visits to each of the apartment complexes.

After we collected the data as per a predefined template, we conducted walk-throughs at each of the apartment complexes to validate the data and observe the usage of the electrical assets. The team conducted the walk-through along with the facility manager and/or the electrician at the complex. This was also used as an opportunity to understand challenges and any other troubleshooting areas on electricity consumption in the

Table 2 | **List of Common Services Studied in the Ten Apartment Complexes**

ASSET CATEGORY	DESCRIPTION
Lighting	All lights in the common area (outdoor and indoor), except lights in elevators
Pumping	All motors and pumps in the common area, except the pumps used in Sewage Treatment Plants (STPs)
Elevators	All elevators, including passenger and service elevators, including the lights, fans, and motors
STP	All electrical components of the STP, including pumps but excluding lighting (if any)
Heating	Electric geysers, sauna systems, and heat pumps for swimming pools
Cooling	Air conditioners, air coolers, ceiling fans, exhaust fans, and table fans used in club-houses, gymnasiums, or other common rooms
Machinery	Organic waste composter, grass-cutting machine, vacuum cleaner
Miscellaneous or Others	CCTV camera and battery, uninterruptible power supply, and others

Source: WRI authors.

common areas. Mapping the electrical assets, meter-wise, was an additional objective of the walk-through process.

Appendix E describes the types of data collected for the services, the data sources and challenges and limitations of the secondary data collection process.

Documenting of Data Inconsistencies, Absence of Data, and Faulty Data

During the process of primary as well secondary data collection, we noted that there were several instances where data were either unavailable, withheld, not consistent, or faulty. For instance, it was observed that for DGs and water pumps the data collected were not reliable due to insufficient reporting on operating hours and rated capacities for some pumps in apartment complexes. In the case of DGs, we observed faulty meters that severely compromised the quality of data. In a second instance, in all apartment buildings, the use of automatic water level sensors, which regulate the operation of pumps, prevented assessment of the pumps' operating hours.

We believed that, although the data shortcomings were an obstacle to creating an objective assessment of energy use in the common areas, these limitations could potentially provide one of the most significant contributions of this study to document the areas where it was difficult or impossible to obtain the requisite data. The availability of complete and correct data will gain greater urgency as policy interventions become more rigorous and stringent and clean energy interventions become more imperative.

Energy Audit Studies for Pumps

During the walk-through, low-performing pumps were identified based on their physical appearance, hours of operation, and the number of times they required rewinding. From among those pumps that were suspected of poor performance in the walk-through, 6 to 10 pumps in each complex were selected for energy audits due to limitations of time and resources and based on the parameters given in Table 3.

To prioritize energy audit studies for select pumps, we discussed with supervisory and maintenance staff the list of pumps that were shortlisted based on these criteria. Sixty pumps were identified for energy audits in seven apartment complexes. The energy audits were done by a BEE-certified energy auditor. The objective of the audits was to determine the overall pumping efficiency, actual power consumption versus rated power consumption, and pump loading during operating conditions. The pumps and their use are given in Appendix F. Pumps used in STPs were not audited.

Data Analysis

The project team analyzed the primary data collected from the apartment complexes. The energy audit experts provided analysis of the data that they collected through their energy audit of the pumps.

Table 3 | **Criteria for Selection of Pumps for Energy Audits**

CRITERION	DESCRIPTION
Age and Physical Condition of the Pump	A mix of pumps of varying ages and physical condition were identified. Most pumps had not been replaced since the beginning of initial occupancy of the apartment complexes. Some pumps had been rewound multiple times, causing them to degrade in performance and efficiency. In some cases, water leakages were observed in the pump system. Very few pumps had been replaced in the last couple of years.
Type of Pump	Either mono-block or submersible pumps are used in residential buildings. The pumps identified for the energy audit represented both these types equally.
Applications	Pumps are used in pumping of water from the sump to overhead tanks, for water treatment, in STPs, and in swimming pools. Pumps used in supplying water for domestic use and swimming pool filtration applications were selected for the study. Also, the application defined the size of the pump, and a good mix of pumps of all sizes for auditing was obtained.
Accessibility of the Pumps	To conduct energy audits, it was necessary to install the measuring instruments and record data along the delivery line of each pump that comprises the piping system, the pump itself, and its motors. In some cases, submersible pumps that were inaccessible could not be selected.
Operating Hours	Pumps that were in use the most were selected.

Source: WRI authors.

Establishing baseline electricity use for common services

To enable comparisons across apartment complexes, 2017 was chosen as the baseline year. Annual electricity uses for common services (from monthly electricity bills) was established using data for three continuous years—2015, 2016, and 2017—for the 10 apartment complexes. To establish the baseline electricity use, the following precautions were taken:

- Validation of the electricity bills collected with utility data. In each apartment building studied, the common area had a minimum of 5 and a maximum of 30 utility meters (also called low tension [LT] connections).
- All the electricity bills were collected and consolidated to establish the annual electricity consumption for the common area. We analyzed both the number of units billed and energy charges. If the electricity bill data were not available, we asked the local utility to provide the consumption data under the purview of a nondisclosure agreement.

Analysis of electricity consumption by service

For all the apartment complexes, we assessed the contribution of each asset or service category to the total energy load in the common area and to the total electricity consumption. For the former, we used data on the power rating of the electrical equipment and appliances. For the latter, even after mapping the electricity bill of the utility meter to specific assets, gaps remained. This was because most utility meters were connected to multiple assets in the common area. For example, a meter might be measuring electricity supplied to a pump, an elevator, and some lights, in which case, obtaining a breakdown of common electricity use disaggregated by service category was not possible for all apartment complexes. For pumps, the use of automatic level controllers in apartment complexes prevented understanding of actual electricity consumption by pumps. We therefore determined the contribution of different services to the total connected load in the common area for the buildings and used assumptions on hours of usage to derive, approximately, the electricity used by all services for four apartment complexes for which a complete mapping of assets to the utility meter was available. Only for these four complexes could we perform a disaggregated analysis of common area electricity use by service type. For the sake of consistency, we are not sharing these analyses in this working paper.

For DG sets, faulty meters prevented accurate assessment of diesel use in at least 6 of the 10 apartment buildings.

Assessing technical potential for EE measures

EE measures are defined as actions taken to increase efficiency through changes in equipment, control strategies, or behavior modification. Technical potential

Table 4 | **List of EE Measures for Different Common Services**

COMMON SERVICES	EE MEASURES
Lighting	■ Replacing inefficient tube lights or incandescent bulbs with energy-efficient LEDs or T5 tube lights ■ Using motion sensors with lights
Pumping of water	■ Using automatic or programmable controllers (time control, level control) ■ Avoiding the throttling of pumps and keeping the valves open ■ Using booster pumps to pump water to greater heights ■ Cleaning the impeller monthly ■ Rewinding pumps not more than two times
Diesel generator	■ Load optimization ■ Maintaining a DG log containing details of diesel procured and used ■ Auto-starters in case of power outages ■ Annual maintenance contracts (AMCs)
Elevators	■ Auto controller for lights and fans at elevator ■ 5-star labeled motors for elevators ■ Regular AMCs

Source: WRI authors.

is defined as the theoretical maximum amount of energy that could be displaced by efficiency, disregarding all non-engineering constraints such as cost-effectiveness and the willingness of end users to adopt efficiency measures (Mosenthal and Loiter 2007). We studied only the technical potential of EE measures in pumping, lighting, and elevators and selected only measures that are available in the market. For DGs, we identified EE measures but did not evaluate their technical potential. We estimated the economic feasibility of lighting improvements. For other services, we contacted vendors and service providers for cost-effectiveness estimates, but they declined to share these estimates without a thorough audit administered by them. The audits were not free, and AOAs were hesitant to contract vendors or service providers without the approval of residents.

Assessing technical potential for on-site renewable energy

In a WRI study (Devi 2018), apartment complexes were found to be familiar with RTS; some of them considering it as a power backup that could replace DGs. We evaluated the potential of only RTS technology as the potential on-site RE technology for the apartment complexes. Our assessments included checking for the availability of roof space, using Google maps, and estimating the capacity or size required to meet common services energy needs partially or completely. We did not take into consideration shadows, load, and generation profiles for this analysis. In some cases, we evaluated the possibilities of introducing RE measures like solar water heaters for swimming pools. The selection of services for this evaluation was decided by member interest and participation in each of the complexes.

Assessing low-carbon pathways for each apartment complex

While energy used in common services result in both scope 1 emissions (from use of diesel in diesel generators) and scope 2 emissions (from use of grid electricity), due to the unreliability of diesel consumption data obtained from apartment complexes, we quantified only the scope 2 carbon dioxide emissions in CO_2 tonnes. The low-carbon pathway for apartment complexes comprises electricity savings that are technically possible from implementation of EE measures and on-site rooftop solar PV meeting a portion of the common area energy use. Both EE and RE scenarios were combined to arrive at the best-case scenario of emissions reductions from common services in apartment complexes.

Studying maximum demand recorded and sanctioned load on utility meters

The analysis of electricity bills for each utility meter indicated the variations in the load sanctioned by the utility and the maximum demand recorded on that meter. It was found that in 6 of the 10 apartment complexes, there was at least one meter on which the maximum demand recorded was a less-than-sanctioned load. This meant bill savings for the consumer, arising from avoiding fixed charges on unused sanctioned load. (See Appendix G for some key definitions and rules of supply of electricity in Bengaluru to apartment complexes.)

Preparation of customized reports for the apartment complexes

For the studied complexes, we prepared a report describing the findings from the energy use assessment exercise and shared it with the AOA MC. The report described the breakdown of connected load, a utility meter-wise mapping of assets and their electricity consumption, an analysis of trends in the utility bill, and a summary of recommendations to save energy through EE and possibilities of on-site renewable energy generation. The reports also described best practices for maintaining and servicing equipment like pumps, DGs, transformers, and elevators.

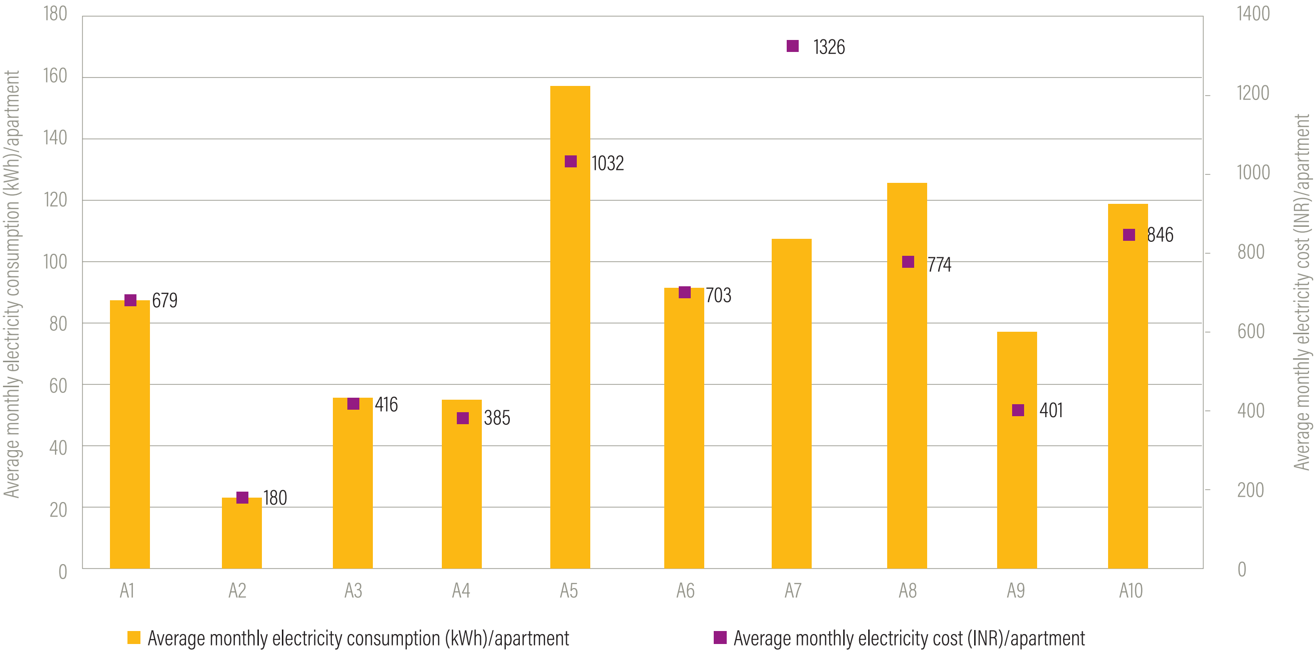
FINDINGS AND OBSERVATIONS

Aggregate Electricity Loads and Annual Electricity Use and Costs to Apartment Complexes

Average annual electricity consumption is affected by factors like number of assets and their usage and existing efficiencies. We were able to obtain the breakdown of annual consumption by different services for only 4 of the 10 apartment complexes. For the remaining 6 apartment complexes, we were unable to capture the contribution of common services to common area electricity use due to the following factors: utility meters serving multiple common services and lack of submetering, and lack of knowledge or records on hours of running of appliances and equipment. Appendix H gives the total sanctioned load, average annual electricity use, and annual electricity costs for common services in the 10 apartment complexes.

There was no visible correlation between size (number of apartments) of the apartment complex and its common area electricity consumption and the cost being paid by each apartment. Figure 3 describes the average

Figure 3 | **Average Monthly Electricity Consumption (kWh/Apartment) and Cost per Apartment (INR/Apartment)**



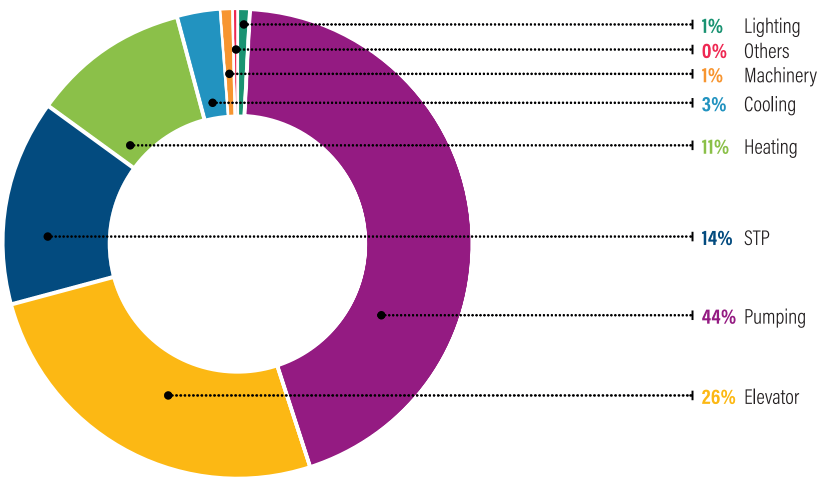
Source: WRI authors.

monthly common area electricity consumption and cost per apartment. At 1,326 INR, A7 with 402 apartments had the highest monthly common area electricity cost, and A2 with 90 apartments had the lowest. The costs variations across the apartment complexes are due to differences in fixed charges and variable charges, the former being a function of the sanctioned load (see Appendix G). We also tried deriving benchmarks in the form of energy performance indices that are measured in kWh/m², but due to the difficulties associated with quantifying the size of common areas and finding the right dataset, we had to drop this analysis.

Contribution of Specific Common Services to Common Area Energy Use

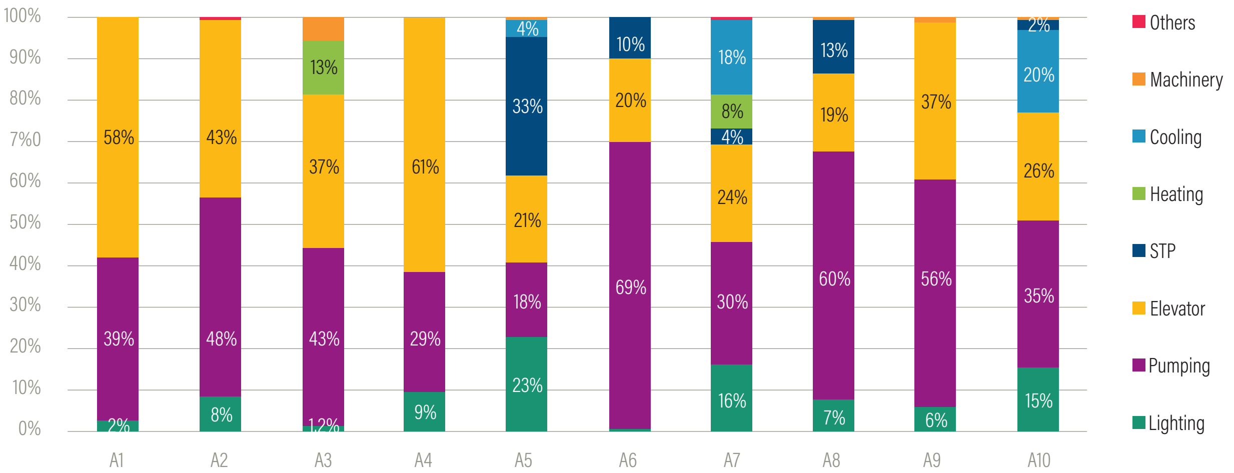
The total sanctioned load for common services of the 10 apartment complexes was 5.3 MW. We calculated the total connected load, which is the sum of the rated power in watts of all electrical appliances in common areas for all 10 buildings. In all apartment complexes except one, assets for pumping, elevators, and lighting were the top three loads in the common area. At an aggregate level, water pumping accounted for 44 percent of the total common area sanctioned load for the 10 apartment complexes (Figure 4). This was

Figure 4 | **Contribution of Common Services to Total Connected Load of Ten Apartment Complexes at an Aggregate Level (%)**



Source: WRI authors.

Figure 5 | **Contribution of Common Services to the Connected Load of Ten Apartment Complexes (%)**



Source: WRI authors.

followed by elevators, which accounted for 26 percent of the connected load. The 14 percent share from STP was attributed to the larger five apartment complexes that had an STP (A5, A6, A7, A8, and A10).

Figure 5 shows the distribution of common services to the total common area connected load of 10 apartment complexes.

Appendix I describes all the electrical assets and services provided in the 10 apartment complexes, which accounts for the variations among apartment complexes. Service-wise analysis of variations in load characteristics is as follows:

- **Pumping:** In smaller apartment complexes A1, A2, A3, and A4 that have fewer than 200 apartments, the pumping load was 39, 48, 43, and 29 percent, respectively. In medium-sized complexes A5, A6, and A7 (between 200 to 450 apartments), the pumping load was 18, 69, and 30 percent, respectively. The variations in the pumping loads across the 10 complexes have been explained in Appendix J. These are primarily attributable to different types of pumps being used in each of the apartment complexes.
- **Lighting:** In apartment complex A5, built in 2012, the lighting load was the highest at 23 percent due to the use of 1,866 LED lights. Walk-through observations showed that these lights were placed incorrectly, and wrongly sized.
- **Elevators:** In all but one complex (A8), there was more than one elevator per floor or block. In A2, the oldest apartment complex, elevators that have not been upgraded since the time of installation contributed to 43 percent of the connected load.
- **STPs:** STPs were present in five apartment buildings (A5, A6, A7, A8, and A10). In unit A5 the number of equipment units serving the functional STP was also the largest, contributing to 33 percent of the total connected load of 410 kW.
- **Others:** In units A3 and A7, facilities like sauna rooms led to heating loads of 13 and 8 percent, respectively. Only four apartment complexes had a cooling load contributed by air conditioners and fans in common areas. In A7, cooling equipment alone was responsible for 18 percent of the total connected load of 696 kW.

Observed Efficiencies and Practices in Lighting, Elevators, and Diesel Generators

- **Lighting:** In 4 of the 10 complexes, common area lighting comprises entirely LEDs. But these are kept on throughout the day in two of the four apartment complexes. In the remaining apartment complexes, part of the lighting needs were being met by LEDs, and inefficient lights continue to be used in walkways and basements. In one apartment complex, we observed LED lights that were oversized, along with overcrowding of lights.
- **Elevators:** Because elevators are sizeable investments, in all complexes these are maintained through AMCs with the vendor. All elevators studied lacked auto controllers or sensors for elevator lights.
- **DGs:** In the case of DGs, only three apartment complexes had digital meters for recording DG generation. All but one complex had poor DG logs (that record consumption of diesel), and in two complexes, audit results indicated that the digital meters were displaying faulty readings. In one

apartment complex, DG loading was found to be inefficient.

Efficiency Analysis of Pumps

The pumping systems were benchmarked based on the overall efficiency of the system comparing the power supplied to the motor in relation to the power output to water. Depending on the pump and the manufacturer, the rated efficiency of pumps (mechanical part) available in the market is around 45 to 70 percent, while the pump motor (electrical part) efficiency can be as high as 85 percent or more. The category of 5–10 horsepower (HP) pumps was the largest, and 28 such pumps were audited. The sample also included 14 pumps of 3–5 HP capacity, 8 pumps of less than 3 HP capacity, and 10 pumps of greater than 10 HP capacity.

The energy audit results for the 60 pumps showed that 22 pumps had an efficiency lower than 25 percent, 27 pumps had an efficiency ranging between 25 and 40 percent, and only 11 pumps had an efficiency greater than 40 percent (Figure 6). A large variation in efficiencies was found within the same size category.

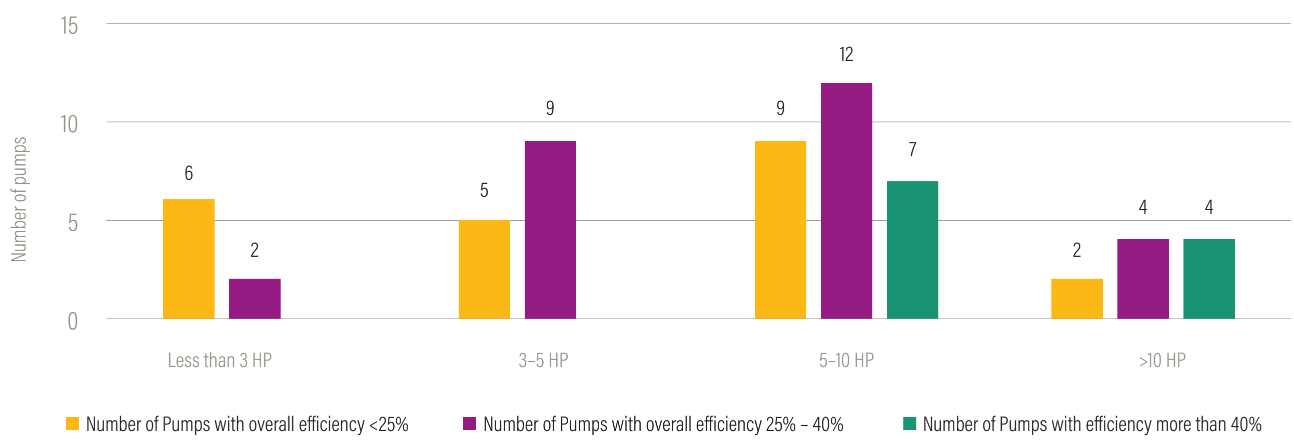
We make the following additional observations, based on findings from pump audits and walk-through assessments of the pumping systems:

- The last decade has seen significant improvements in pumping technologies, and new pumps are more efficient. However, the 10 apartment complexes studied have not replaced their pumps with newer ones, despite their age and inefficiencies, and have continued to rewind pump motors, contributing to a further decline in energy performance.
- BEE's standards and labeling program prescribes energy performance standards for domestic pumps, but, critically, none of the pumps were star labeled or complied with the performance benchmarks.
- Due to poor water quality in some of the apartment complexes, we observed plumbing leakages, corrosion, and wear and tear of pumps. Pumps were installed after the completion of construction and before the residents moved in. In all apartment complexes, we found oversized pumps.
- All apartment complexes practiced troubleshooting only at the time of a breakdown of the pumps. Motor rewinding was used as the solution in all cases. We could not find any instances of standard maintenance practices implemented by supervisors or electricians for pumping systems. This is unlike that for elevators and DG sets where AMCs are quite common.

Analysis of Diesel Generators

All studied apartment complexes had backup power supplied through DGs. All DGs had automatic starters that are switched on immediately after an outage. In case of an outage, full power backup is available for common services like elevators and pumping. In all cases, the generators provided partial power backup to the apartments in each complex during an outage. Out of 10 apartment buildings, 7 had more than one DG. In most cases the size of the DG was determined by the builder and handed over to residents. We also found that multiple DGs were operating in either a standby mode (only one DG working with the other acting as standby in two complexes) or in the active mode (both DGs working simultaneously and sharing the load of services needed, as was the case in five complexes).

Figure 6 | **Efficiency of Studied Pumps per Size Category**



Source: WRI authors.

In 4 out of 10 complexes, the logs of DG usage (i.e., recorded number of hours of their operation) were missing or unreliable and were not considered for further analysis. In the remaining 6, we found that DGs were running between 100 to 200 hours annually and, in two complexes, between 200 to 400 hours annually (or approximately one hour daily).

We did not conduct an efficiency analysis of DGs due to unreliable datasets. As part of the recommendations report, the apartments without proper data recording practices were provided with templates to maintain logs of DGs. Other barriers faced in analyzing and benchmarking energy performance of DGs were unavailability of the manufacturer's load-versus-efficiency curves for benchmarking based on the make or model or types of engines, the use of analog meters for recording the power generated by the DG, and calibration details.

Load Sanctioned on Utility Meters Versus the Maximum Demand Recorded

We found that in 7 of the 10 apartment complexes, there was at least one meter on which the maximum demand recorded was less than the sanctioned load by 50 percent. This indicated that in these complexes the consumers were paying higher fixed charges and therefore higher electricity bills for demand that was unused. There was observable potential to surrender excess sanctioned load resulting in significant cost savings to the apartment buildings. We came across three utility meters in the 10 apartment complexes where the maximum demand recorded exceeded the sanctioned load. Apartment complex specific highlights are described in Table 5.

In the report customized for each apartment complex, we provided behavioral change and housekeeping recommendations that could increase the life of the electrical appliances by reducing their deterioration rate. These reports were shared with each apartment complex, complete with economic analysis and with payback periods of the most important clean energy interventions to encourage their quick adoption by the AOAs.

We estimated the technical potential of energy savings in percentage terms based on literature and inputs from vendors, service providers, and experts. The total energy savings potential from EE measures in lighting, pumping, and elevators ranged from 1 to 20 percent in the 10 apartment complexes (Table 6). The estimates of energy savings potential from the measures are conservative at best. These were largely determined based on feasibility and ease of doing these interventions. We did not conduct an in-depth analysis of each measure but recommended those that were identified during the walk-through and discussions with building supervisors and AOAs. In the case of pumping, the energy savings potential ranged from 1 to 16 percent, based on the results of the energy audits of the pumps for those complexes. Because we could only audit some pumps in each apartment complex, the potential savings in energy and costs varied, depending on the existing efficiencies of the audited pumps.

Table 5 | **Observations on Maximum Demand Recorded and Sanctioned Load on Common Area LT Meters**

APARTMENT COMPLEX	OBSERVATIONS ON MAXIMUM DEMAND RECORDED VERSUS SANCTIONED LOAD
A3	16 out of the 20 utility meters had not recorded any consumption, and fixed charges were being paid for 85 kW of unused sanctioned load.
A4	The only utility meter supplying to common area amenities had recorded maximum demand of 26% of the sanctioned load.
A6	6 out of 9 utility meters had maximum demand recorded of less than 20% of the sanctioned load.
A7	1 out of 10 utility meters had maximum demand recorded of 3% of the sanctioned load.
A9	1 out of 30 utility meters had maximum demand recorded of less than 40% of the sanctioned load.
A10	10 out of 26 utility meters had maximum demand recorded of less than 40% of the sanctioned load.

Source: WRI authors.

Table 6 | **EE Measures in the Ten Apartment Complexes, Percentage of Monetary Savings, and Percentage of Energy Savings Technically Possible**

APARTMENT COMPLEX	EE INTERVENTION CATEGORY	EE INTERVENTION	ANNUAL ELECTRICITY COST SAVINGS (%)	ANNUAL ENERGY SAVINGS TECHNICALLY POSSIBLE (%)
A1	Pumping	Avoiding the use of sump pumps and replacement of inefficient sump pumps with energy-efficient pumps	16%	20%
	Elevators	Use of motion sensors for fans, lights	2%	
A2	Lighting	Switching to LED lighting for outdoor walkways	7.5%	12%
	Elevators	Auto controllers for lights	2.3%	
A3	Lighting	Replacement of 112 PL lights with LEDs and 40 T5 tube lights with T12	3.5%	12%
	Pumping	Replacement of 3 HP and 5 HP swimming pool filtration pumps with energy-efficient pumps	6%	
	Elevators	Auto controllers for lights	3%	
A4	Elevators	Auto controllers for lights	2%	1%
A5	Lighting	Switching to LED lights	8%	10%
	Elevators	Auto controller for lights	2%	
A6	Lighting	Switching to LED lights	3.5%	6%
	Elevators	Auto controller for lights	2.5%	
	Pumping	Replacement of filtration pump with efficient pump	1%	
A7	Lighting	Switching to LED lights	8%	9%
	Elevators	Auto controller for light	1%	
A8	Elevators	Auto controller for light	1%	3%
	Pumping	Replacing inefficient pumping system with energy-efficient pumps	3%	
A9	Lighting	Switching to LEDs	2.5%	8%
	Elevators	Auto controller for lights	3%	
	Pumping	Replacing inefficient pumping system with efficient pumps	3%	
A10	Lighting	Switching to LEDs	13%	14%
	Elevators	Auto controller for lights	1%	
	Pumping	Auto controller for lights	2%	

Source: WRI authors.

Recommended Rooftop Solar PV for Common Services

To determine the feasibility of RTS, we looked at the availability of roof space without accounting for the competing uses[6]. Most apartment complexes had enough roof space available to install RTS that could meet the entire common area energy needs. But practically, in WRI studies (Martin and Ryor 2016; Devi et al. 2018) to understand barriers and experiences with RTS in Bengaluru, the authors found that, even if consumers were interested in installing RTS, they faced the following major barriers:

- Lack of objective information on different aspects of RTS projects, including access to quality vendors and technology, system costs, and payback periods
- Absence of favorable financial instruments to meet the high up-front cost of RTS

We assessed rooftop space in 10 apartment complexes using Google Maps. The assumptions that the Ministry of Renewable Energy (MNRE n.d.) used in estimating solar generation were 60 percent of shadow-free roof area available for installation; average sunshine hours of 5.5 per day, the average solar radiation in Karnataka being 1,266.52 W/m^2; 1 killo watt peak (kWp) plant generating 5 units per day; and a capacity utilization factor of 17 percent.

Cumulatively, the rooftops of the 10 apartment complexes can be used to install solar panels of up to 2.4 MW, generating 3.6 million units of power. For 8 of the 10 apartment complexes, it was technically possible to meet the entire energy demand for common services from RTS, while for A5 and A10, 50 and 25 percent, respectively, of common area energy needs could be met through RTS (Table 7).

CLEAN ENERGY PATHWAYS FOR COMMON AREA ENERGY USE IN APARTMENT COMPLEXES

CO_2 emissions from consumption of electricity for common services were counted as scope 2 emissions. The total scope 2 in BAU or baseline emissions from consumption of grid electricity in the 10 apartment complexes were 4,274 tons of CO_2.

Our low-carbon energy pathway recommendations comprised EE and RTS as measures to mitigate scope 2 emissions from common area electricity use. We examined the impact of the following four scenarios on BAU or baseline:

- **EE only scenario:** Assessment of reduction in BAU CO_2 emissions if only EE measures described in Table 4 are implemented. At their conservative best, the application of EE measures alone results in emissions reductions ranging from 4 (A8) to 20 percent (A1).
- **RTS only scenario:** Assessment of reduction in BAU CO_2 emissions if only RTS measures are implemented across all 10 apartment complexes to meet common area energy needs. If only on-site RTS measures are incorporated, 8 of the 10 apartment complexes could technically generate

Table 7 | **Technical Potential for Rooftop Solar in Ten Apartment Complexes**

APARTMENT COMPLEX	ROOFTOP AREA AVAILABLE (M^2)	FEASIBLE PLANT SIZE AS PER THE ROOFTOP AREA (TECHNICAL POTENTIAL) (KWP)	ANNUAL POWER GENERATION (KWH)	AVERAGE ANNUAL ELECTRICITY CONSUMPTION (KWH)	COMMON AREA ENERGY NEEDS MET
A1	1,760	105	158,400	41,993	100%
A2	1,201	72	108,150	26,898	100%
A3	3,200	192	288,450	114,963	100%
A4	1,732	104	155,850	125,770	100%
A5	2,400	146	219,150	429,643	50%
A6	5,600	336	504,000	426,907	100%
A7[1]	6,700	402	603,000	520,238	100%
A8	8,096	485	728,700	728,268	100%
A9	6,907	414	621,600	555,442	100%
A10	2,416	145	217,500	2,242,422	25%

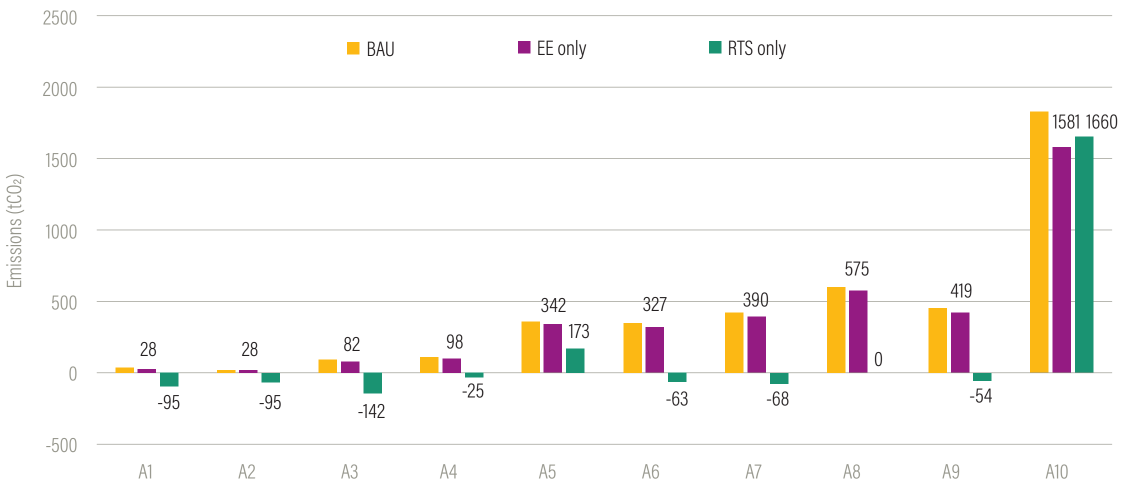
Source: WRI authors.

all the energy needed for common area energy use, thereby offsetting all emissions related to grid electricity. In each of these eight apartment complexes, RTS could technically generate more than the energy needed for common area consumption, effectively resulting in negative emissions and making common area energy use net zero. For A5 and A10 due to lack of space, RTS of smaller capacity was found to be feasible, which could meet 50 and 25 percent of the total common area electricity needs, respectively.

- **EE + RTS scenario 1:** Assessment of reduction in BAU CO_2 emissions if RTS projects are implemented after implementation of all EE measures. This scenario assumes that complete RTS capacity feasible for installation with the given roof area for the apartment complexes is available. When RTS is used to meet reduced energy demand after applying EE measures, the percentage of negative emissions increases. This combination could still meet 100 percent of the common area electricity needs in eight apartment complexes.

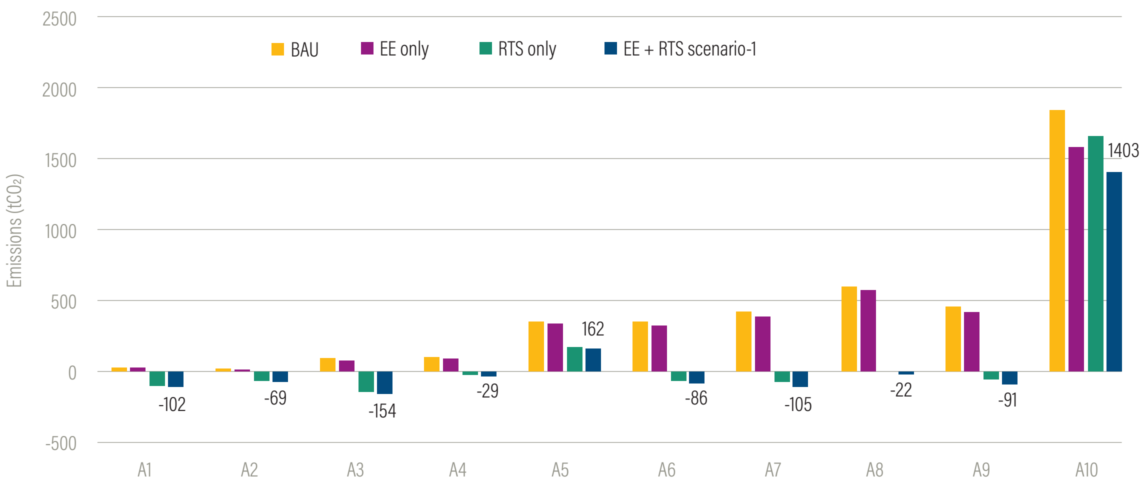
- **EE+RTS scenario 2:** Assessment of reduction in CO_2 BAU emissions with the RTS capacity only required to meet reduced energy demand after application of all EE measures. Incorporating EE measures significantly reduced the size of the RTS project needed for the apartment complex, still meeting total common area electricity needs of eight apartment complexes and resulting in zero common area energy emissions. At an average, a reduction of RTS capacity by up to 20 percent was observed across the 10 apartment complexes due to incorporation of EE measures. In A5 and A10, the entire RTS capacity feasible must be installed to meet 50 and 25 percent, respectively, of the

Figure 7 | **BAU Emissions Compared to EE and RTS Only Scenarios**



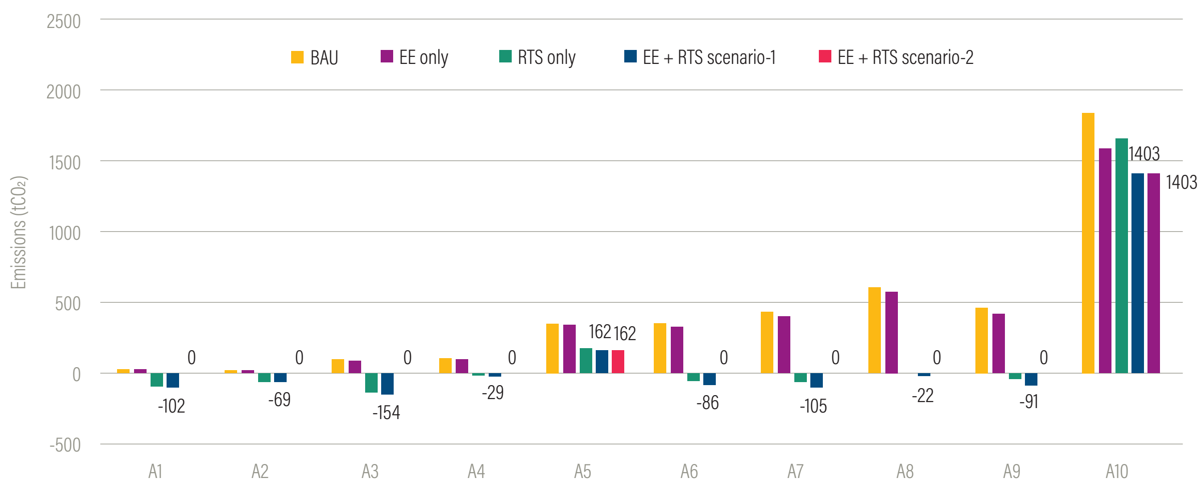
Source: WRI authors.

Figure 8 | **BAU Emissions Compared to EE+RTS Scenario 1**



Source: WRI authors.

Figure 9 | **BAU Emissions Compared to EE+RTS Scenario 2**



Source: WRI authors.

common area energy needs even after implementing EE measures. For these two apartment complexes, the remaining energy needs will need to be provided from the grid. Figures 7 through 9 describe the emissions under different scenarios. Appendix K describes the emissions in ten apartment complexes under different clean energy pathway scenarios.

STAKEHOLDER ENGAGEMENT

We conducted discussions with the MC members of the 10 apartment complexes and presented the analysis and recommendations on the clean energy projects, accompanied by economic assessments of these recommendations. To facilitate the implementation of the recommendations, we shared a list of EE and RTS vendors and service providers. In order to overcome the hurdles of unavailable or unreliable data, we generated an MS Excel spreadsheet-based tool and presented it for AOAs to continue to record and track their energy bills and data on common area assets. We also helped them engage with vendors and service providers. At the time of this paper, some of the recommendations have been implemented.

Although we found it feasible to technically aggregate energy demand in common areas and identify EE measures to reduce the demand and implementing RE measures to meet a portion of this demand, there were barriers to the practical feasibility of implementing clean energy projects (EE and RE) for common areas in apartment complexes. To collect evidence of these barriers, we conducted semi-structured interviews with the primary stakeholders (Table 8). These stakeholders have a direct stake in decisions related to managing energy use in common services or are directly affected by these decisions. The stakeholders can be further categorized into primary stakeholders on the demand side and those on the supply side. The primary stakeholders on demand side are apartment residents, AOAs, and facility managers or supervisors. Supply-side primary stakeholders include vendors of EE products and services and vendors of RE products and services.

Typically, after one to two years of occupancy of the apartment building, developers relinquish control of maintenance and management of apartment buildings to the AOA. All apartment owners are members of the AOA, which is managed by the MC. Members of the

Table 8 | **Role of Primary Stakeholders in Decision-Making on Clean Energy Projects**

DRIVING GROUP	POLITICAL DECISION-MAKERS	TECHNICAL SUPPORT	INTEREST AND OPINION	FINANCIAL ASSISTANCE
■ AOA MC member(s) ■ Apartment residents	■ AOA MC	■ Apartment building facility supervisor ■ EE product vendors and service providers ■ RE product and service providers ■ Independent experts and Civil Society Organizations	■ Apartment residents	■ AOA maintenance and corpus or other budgets

AOA weigh in on decisions that involve substantial expenditure for projects in the common areas. There are also secondary stakeholders: the utility BESCOM, the municipal corporation BBMP, builders or developers, and financing institutions or banks. We did not engage with them during this study. In Appendix L, we have described in detail the roles of the different primary and secondary stakeholders in ensuring the success of clean energy interventions through the demand aggregation model.

Key Findings from Stakeholder Consultations

The feedback from the consultations with primary stakeholders and the semi-structured interviews is summarized as follows:

- **Actions on energy upgrades were not pursued due to significant time and effort and cost investments and multiple approvals required.** Most AOAs function on the administrative model of requiring approvals from all (or a quorum) of the AOA MC members for any projects for common areas exceeding a certain budget. This process can be time-consuming especially because MCs comprise voluntary residents who work part-time and only meet on weekends when most members are available. This issue is compounded by the fact that AOA MCs often have a tenure of one year, and hence there is no continuity of decision-making or knowledge transfer from year to year. Given the long process of decision-making and even longer time frame for complex technical projects needing large investment, vendors and service providers are hesitant to approach AOAs. RESCOs and ESCOs believe that, while they are willing to offer turnkey support to the project, they are not entertained by AOAs due to lack of trust. One RESCO highlighted delays in payments and finalization of power-purchase agreements as a big barrier to approaching AOAs for RTS.
- **Lack of objective information on best practices and capacity to implement clean energy measures in house is a barrier.** Due to lack of access to objective and reliable sources of information on technical and financial aspects (return on investment and payback periods), projects may not be seriously considered by AOAs, even by those who are interested in principle. In the case of RTS, AOAs are unfamiliar with government policies, regulations, and incentives to promote RTS. EE vendors and service providers and RESCOs are often met with resistance from AOAs when they introduce RTS or energy-efficient pumps, as the AOAs often operate under the belief that the vendors only promote and sell products to make profits. AOA members interviewed said that if they had access to examples of these measures being successfully adopted in other apartment complexes in the city, they would be more likely to be able to convince residents about the benefits. On the flip side, vendors and service providers shared that, despite their best efforts, AOA MC members fail to understand technical aspects of clean energy measures and the limited maintenance required. Additionally, facility managers, supervisors, electricians, and plumbers in the apartment complexes studied were found to have very little understanding of EE measures and RE technologies. They were, however, interested in attending training programs to enhance their skills in EE measures and maintenance of RTS projects.
- **Competing priorities for management budgets mean limited interest in EE measures.** A single annual budget is drawn up for all expenses related to maintenance, operations, and management of common areas in the complex. If the electricity bill has not seen a significant change annually, it is not a concern for anyone in the MC. MC members would rather concern themselves with other demanding (e.g., increasing water availability, installing an STP to comply with BBMP rules), more visible (e.g., installing a new composter for managing waste), or attractive (e.g., more gym equipment) needs. Vendors and service providers find it difficult to effectively sell even financially attractive clean energy projects to AOAs if energy bills are a low priority. EE vendors also commented that for apartment complexes, cost is a larger concern than the energy efficiency of new products like energy-efficient pumps or elevators. One elevator vendor added that most AOAs tend to change elevators only when licenses are expiring and that, despite efforts to educate residents about energy-saving benefits, decisions are made solely based on cost.
- **Motivations to implement clean energy measures are driven by economics or environment.** Despite competing priorities, AOAs that participated in this study were concerned about rising electricity costs and their implications on the annual budget and were keen to investigate and identify steps to reduce energy use. Some of the complexes were also keen to consider EE and RE measures from an environmental perspective. In one apartment complex, an RTS project was voted

for unanimously by AOA members, despite the high investment needed, to gain gradual independence from grid electricity and safeguard themselves from electricity tariff inflation.

- **There are regulatory and process barriers to RTS projects for residential buildings.** As per Karnataka's solar policy, the capacity of small RTS projects is limited to 100 percent of the total sanctioned load of the consumer (KERC 2016). Apartment complexes with small sanctioned loads but large roof areas are forced to opt for smaller capacity RTS. RESCOs highlighted that BESCOM has made efforts to simplify approval of RTS projects, but there continue to be several stages of approvals and incorrect billing due to untrained ground personnel; and this creates mistrust in consumers and problems for solar vendors.
- **Competing uses for the rooftop and technical constraints limit implementation of RTS projects.** Even with the availability of physical space for an RTS project, AOAs are hesitant to use it for solar generation citing alternative uses like hosting events and access to residents.[4] Solar rooftop vendors interviewed cited limitations on the size of RTS plants posed by technical constraints for elevated solar panels like shadows from surrounding buildings and high winds that limit the capacity that can be installed. The presence of water tanks and fire lines also limits installation of solar panels. Because wiring to the panel runs from the ground to the rooftop, in case of high-rises, this is a major safety concern faced by RESCOs.

CONCLUSIONS

The case for adopting efficiency and RE measures through demand aggregation in the common areas of apartment complexes currently appears to require wider research and be actively supported by behavior-modification and awareness initiatives in order to be considered viable. Our study made the following three observations on the practical challenges for the successful implementation of demand aggregation for accelerating clean energy in apartment complexes:

- **Organized efforts to introduce clean energy interventions are not easy.** High investment initiatives like RTS, despite their technical and economic feasibility, suffer from mistrust built on a lack of information and technical and capacity constraints on the ground from both supply and demand sides. Other pressing and urgent issues like water and waste management take priority over energy management. A lack of awareness in residents who are all members of the AOAs, leads to the hidden consumption being paid for in maintenance and often accounts for the lack of support for MC members that champion energy conservation in common services.
- **An information barrier continues to prevent even interested complexes from undertaking clean energy projects.** Platforms to disseminate good practices and share opinions and expertise on energy management are absent. In the absence of benchmarks and energy performance targets for services like water pumping and common area lighting, which as our study highlights, varied significantly across the 10 apartment buildings, there is no push for builders to optimize building design or assess correct sizes for assets and their optimal placement. In all the studied apartment complexes, there was no replacement of pumps or elevators after the initial construction and occupancy. This has led to a lock-in effect on inefficient appliances and equipment.
- **Data collection and monitoring of electricity and diesel use for common services are big hurdles.** The lack of data and information ensures that there is little focus on managing energy usage. For example, six apartment complexes were paying high energy bills for a sanctioned load that they were not using, another legacy issue imposed by the builder at the time of the original application for an electricity connection.

THE WAY FORWARD

As of July 2019, three apartment complexes have acted on the recommended clean energy measures, particularly on energy-efficient lighting and installing RTS. At least one complex has changed its pumps to energy-efficient pumps. One apartment complex, A7, has installed a 48 kWp RTS system. Three apartment complexes have initiated steps to install solar water heaters for swimming pools, solar water pumps, and motion sensors for lighting.

While aggregating demand at the common area scale for apartment complexes is feasible, implementing clean energy measures to reduce this demand faces the following barriers:

- **Behavioral:** In all cases, apartment owners understand common area energy consumption and inefficiencies only after occupation. While builders advertise the amenities, they do not declare their energy footprint nor the costs that residents will have to bear. Despite the high expenditure on electricity for common areas, it is not high enough to motivate AOAs to act, and there is a preference to delay actions to make even minor replacements (e.g., replacing old CFLs with LEDs) and continue using inefficient equipment until its end of life (e.g., multiple rewinding of water pump motors). Billing common services at domestic tariffs does not incentivize saving energy or implementing RTS which has long payback periods due to the tariff structure.[5] There is no policy or regulatory requirement for apartment complexes to conserve energy. At a minimum, mandatory builders' self-declarations on life cycle costs of common assets could help consumers make informed choices. BEE's labeling program for residential buildings, launched in 2019, must address this.

- **Governance and management challenges:** While the governance structures for management of common amenities are formalized through registration, the decision-making varies across apartment complexes. Organized efforts to introduce clean energy interventions are difficult unless AOAs work together. High investment initiatives like RTS, despite their technical and economic feasibility, suffer from mistrust built on lack of information as well as technical and capacity constraints on the ground from both supply and demand perspectives.
- **Technology adoption:** Vendors provide support for servicing elevators and DGs, but there are no organized maintenance services for water pump systems. There is a business opportunity to offer energy performance contracting services for elevators and pumps. Programs that can aggregate demand for efficient products for a cluster of apartment complexes in the same neighborhood can be considered. This is also true for RTS, a technology that can be implemented through collaborative procurement of solar (Thanikonda et al. 2015). Given that ground personnel, operations staff, supervisors, and electricians and plumbers who are employed by apartment complexes are largely untrained or unskilled to run electrical assets optimally, the programs can also cover training these staff to improve their skills. Some AOAs have corpus funds in fixed deposits that can be used to invest in clean energy interventions through capital expenditure–based RESCO models. Support programs can also be made available for AOAs that want to pursue clean energy interventions but don't know where to start due to the absence of templates or tools for collecting and analyzing data. The creation and dissemination of good practice guides for the management of common services can be helpful. For example, the city of Melbourne has a guide providing an overview of facilities management in multi-unit residential buildings, focusing on common areas and shared services (Facilities Management Association of Australia 2012).

While Bengaluru's skyline and landscape have transformed rapidly in the last few decades with apartment complexes of all sizes and heights, there is no publicly available dataset on the number of apartment buildings in Bengaluru and their growth. This is suboptimal for at least two reasons: the contribution of apartment complexes to the resource footprint of the city is significant yet incalculable at the present time, and real estate trends indicate that new apartment projects will continue to be launched every month. While municipal waste and water issues, being visible manifestations of unplanned growth, are highlighted in Bengaluru, electricity consumption is a serious issue, too; one that needs far greater and more urgent attention.

There are platforms evolving now to meet these needs for information sharing and crowd sourcing data. For example, the Bengaluru Apartments Federation, a body of 500 AOAs, has begun working with solar vendors to increase the uptake of RTS projects in Bengaluru's apartment complexes. It is working toward getting 1,000 apartment complexes in Bengaluru to implement RTS in the next two years[6].

By capturing the baseline and identifying the gaps and barriers through stakeholder consultations, this study is useful to chart future strategies at the level of the AOAs, market players, and policymakers to accelerate adoption of clean energy measures in existing and new apartment complexes. Although the sample size of the study was small, the study provides an opportunity to initiate a dialogue on the challenges and opportunities in reducing the energy footprint of apartment complexes in cities. The study should lead to mainstreaming this dialogue among the various stakeholders identified in the study as well as within a wider community. Finally, this study highlights the fact that there are opportunities to conduct larger-scale benchmarking studies on common area energy use that can help establish factors responsible for high consumption and drive the global thrust toward decoupling floor area growth and emissions in India's booming residential building sector.

APPENDICES

APPENDIX A.

Table A-1 | **Technical Definitions of Apartments, Apartment Buildings, and Common Areas or Services Available in Bengaluru**

TERMS	DEFINITIONS AS PER		
	Karnataka Municipalities Model Building Bylaws 2017 (Urban Development Department 2017A)	**Building Bylaws 2003 (bbmp 2003)**	**Karnataka Apartment Ownership Act 1972 (Government of Karnataka 1972)**
Apartment	A suite of rooms that is occupied or that is intended or designed to be occupied by one family for living purposes in an apartment building. This word is synonymous with residential flat.	A part of the property intended for any type of independent use, including one or more rooms or enclosed spaces located on one or more floors (or part or parts thereof) in a building, intended to be used for residential purposes and with a direct exit to a public street, road, or highway or to a common area leading to such street, road, or highway	A part of the property intended for any type of independent use, including one or more rooms or enclosed spaces located on one or more floors (or part or parts thereof) in a building, intended to be used for residential purposes and with a direct exit to a public street, road, or highway or to a common area leading to such street, road, or highway
Apartment Building	Also called group housing, means one or more buildings, each containing more than four apartments	Also referred to as multi- dwelling units, means a building containing four or more apartments or dwelling units, or two or more buildings, each containing two or more apartments or dwelling units with a total of four or more apartments or dwelling units for all such buildings and comprising all or part of the property	Referred to as a building and defined as a building containing four or more apartments or two or more buildings, each containing two or more apartments, with a total of four or more apartments for all such buildings, and comprising a part of the property
Common Areas or Common Services or Common Facilities	Not available	Not defined directly. Section 9.10.3 states that the floor area of a building shall be the aggregate area of the floors of all parts of the building, including thickness of walls, parking area, staircase rooms, elevator rooms, ramps, escalators, machine rooms, balconies, ducts including sanitary ducts, water tanks, lobbies, corridors, foyers, and such other parts provided for common service	Common areas or facilities thereto mean (1) the land on which the building is located; (2) the foundations, columns, girders, beams, supports, main walls, roofs, halls, corridors, lobbies, stairs, stairways, fire escapes, entrances, and exits of the building; (3) the basements, cellars, yards, gardens, parking areas, and storage spaces; (4) the premises for the lodging of janitors or persons employed for the management of the property; (5) installations of central services, such as power, light, gas, hot and cold water, heating, refrigeration, air conditioning, and incinerating; (6) the elevators, tanks, pumps, motors, fans, compressors, ducts, and in general all apparatus and installations existing for common use; (7) such community and commercial facilities as may be provided for in the Declaration; and (8) all other parts of the property necessary or convenient to its existence, maintenance, and safety, or normally in common use

APPENDIX B.

Table B-1 | **Policy and Regulatory Support to Renewable Energy Projects in Residential Buildings**

POLICY/REGULATION	AGENCY	DESCRIPTION
Implementation of Solar Rooftop Photovoltaic Power Plants Regulations, 2016 (KERC 2016)	Karnataka Electricity Regulatory Commission	As of March 18, 2018, tariff per unit for grid connected RTS projects of 1 MW and below at Rs.3.56 (without capital subsidy) and at Rs.2.67 per unit (with capital subsidy). The total capacity of the existing RTS and proposed RTS plants on that distribution transformer shall not exceed 80% of the "rated capacity" of that line. RTS plant of less than 50 kW capacity shall be connected only to the existing distribution transformer through which the eligible consumers are being supplied electricity
Karnataka Municipalities model building bylaws 2017 (Urban Development Department 2017a)	Government of Karnataka Department of Urban Development	For Group Housing a minimum 5% of connected load or 20 W/ft^2 for "available roof space" (70% of the total roof size, considering 30% area is reserved for residents' amenities), whichever is less. There are also provisions for energy-efficient alternate heating systems including heat pumps, mandatory Installation of solar water heaters for all new residential buildings; compliance with ECBC, use of LED lighting in common areas, and BEE star-labeled appliances
Building bylaws 2003 (BBMP 2003)	BBMP	Solar water heater mandatory for buildings having 200 m^2 floor area or 400 m^2 of site area and 500 liters per day for multi-dwelling units or apartments for every 5 units and multiples thereof. Solar photovoltaic lighting systems shall be installed in multi-unit residential buildings (with more than 5 units) for lighting the setback areas, driveways, and internal corridors
Electricity bill rebate (BESCOM 2018)	Bengaluru Electricity Supply Company (BESCOM)	A rebate of 50 paise per unit of electricity consumed subject to a maximum of Rs.50 per installation per month will be allowed to tariff schedule LT 2(a), if solar water heaters are installed and used. Where a bulk solar water heating system is installed, a solar water heater rebate shall be allowed to each of the individual installations, provided that the capacity of solar water heater in such apartment/group housing shall be a minimum capacity of 100 L/household

APPENDIX C.

Table C-1 | **List of Case Studies of EE and RE Projects for Common Areas in Indian Cities**

NAME OF APARTMENT	LOCATION	NUMBER OF APARTMENTS	RE/EE INTERVENTIONS ADOPTED	IMPACTS OR IMPLICATIONS	SOURCES
ARK Serene County	Bengaluru	NA	106 kWp rooftop solar PV	Monthly electricity bill reduction of up to 25%	Mehrotra 2019b
Brigade Petunia	Bengaluru	49	96 kWp rooftop solar installed, with a break-even period of 7 years of 16% (internal rate of return)	In September 2018, apartment complex achieved zero electricity bills for common areas as 100% needs were met by rooftop solar	Solarify 2019
Mittal Auriga	Bengaluru	12	10 kWp for common services and an additional 10 kWp for power backup	Bengaluru's only carbon-neutral apartment complex. Monthly energy savings of 4,000 units in total for apartments and common area energy use and monthly bill savings of INR 10,000	Smarter Dharma 2019
Woodstock	Bengaluru	63	10 kWp for common services	Monthly electricity bill savings of INR 10,000	Solarify 2017
Mantri Astra	Bengaluru	149	20 kWp rooftop solar for common services	Monthly electricity bill savings of 10%	Mehrotra 2019a
Chartered Coronet Apartments	Bengaluru	NA	20 kWp rooftop solar for common services	Projected monthly electricity bill savings of INR 16,000 to Rs. 18,000	Mehrotra 2019a

NAME OF APARTMENT	LOCATION	NUMBER OF APARTMENTS	RE/EE INTERVENTIONS ADOPTED	IMPACTS OR IMPLICATIONS	SOURCES
Raheja Eternity	Mumbai	229	EE measures like LED bulbs and motion sensors for lighting in stairways and parking areas.	40% reduction in energy use. Summer electricity bill down from INR 359,000 to INR 5,000	Sakaria 2017
Lunkad Sky Lounge Society	Pune	NA	12 kWp of rooftop solar	Rooftop solar meets about 47% of the energy consumed for water pumping	GKSPL and Prayas (Energy) group 2017
Royal Orange County	Pune	NA	20 kWp SPV system and 104 m^2 of solar water heater installed on one of the towers, which is 11 stories high and has 44 flats. All flats in the tower have both SPV and grid electricity	The free supply from the SPV system flat is fixed at 300 W per flat. Residents have incentive to conserve energy and make energy-efficient choices.	GKSPL and Prayas (Energy) group 2017
3-story building in Najafgarh	Delhi	NA	7 kWp rooftop solar with battery backup	Estimated payback period of 11–13 years	GKSPL and Prayas (Energy) group 2017

APPENDIX D.

Table D-1 | **Summary of TEN Apartment Buildings Studied**

SL.NO	APARTMENT COMPLEX NOMENCLATURE, LOCATION, YEAR OF POSSESSION	NUMBER OF FLOORS AND TOWERS	NUMBER OF FLATS	COMMON FACILITIES IN ADDITION TO COMMON AREA LIGHTING, PUMPING, AND ELEVATORS
1	A1 Location: Hebbal Year of possession: 2011	5 floors 1 tower	40	Clubhouse Gym Play Area Tennis Court Community Hall
2	A2 Location: Malleshwaram Year of possession: 1986	9 floors 3 towers	96	None
3	A3, Location: Hebbal Year of possession: 2004	4 floors 13 towers	171	Clubhouse Gym Swimming Pool Play Area
4	A4 Location: JP Nagar Year of possession: 2007	16 floors 1 tower	190	Clubhouse Gym Swimming Pool Play Area Tennis Court Meditation Hall Indoor Games Badminton Court
5	A5 Location: Harohalli Year of possession: 2012	16 floors 3 towers	202 (and 26 row houses)	Clubhouse Gym Swimming Pool Play Area Tennis Court Indoor Games Meditation Hall Library

SL.NO	APARTMENT COMPLEX NOMENCLATURE, LOCATION, YEAR OF POSSESSION	NUMBER OF FLOORS AND TOWERS	NUMBER OF FLATS	COMMON FACILITIES IN ADDITION TO COMMON AREA LIGHTING, PUMPING, AND ELEVATORS
6	A6 Location: Doddenakundi Year of possession: 2010	12 floors 10 towers	387 flats	Clubhouse Gym Play Area Tennis Court Basketball Court Indoor Games Swimming Pool Badminton Court
7	A7 Location: BTM 2nd Stage Year of possession: 2008	18 floors 3 towers	402 flats	Clubhouse Gym Swimming Pool Play Area Tennis Court Basketball Court Badminton Court Indoor Games
8	A8 Location: Jallahali Year of possession: 2008	11 floors 14 towers	482 flats	Clubhouse Gym Swimming Pool Play Area Tennis/Badminton Court Meditation Hall Indoor Games
9	A9 Location: Bilekahalli Year of possession: 2002	9 floors 10 towers	600 flats	Clubhouse Gym Swimming Pool Play Area Tennis Court Indoor Games Meditation Hall
10	A10 Location: J P Nagar Year of possession: 2010	19 floors 19 towers	1573 flats	Clubhouse Basketball Court Swimming Pool Play Area Tennis/Badminton Court Gym Indoor Games

Source: WRI authors.

APPENDIX E.

Table E-1 | **Data Collected to Establish Baseline Energy Use in Common Services, Limitations and Challenges Faced**

CATEGORY	TYPE OF DATA	DATA SOURCE	LIMITATIONS/CHALLENGES
BESCOM (Utility) Assets	The number and location of electricity meters that supply power to common services; number of transformers with their rated capacities	Walk-through assessments and interactions with supervisors	For some assets, supervisors were unclear which meters they are connected to
Electrical Assets in Common Area	The list of electrical equipment and appliances with their number, power ratings, and usage; a mapping of the number and type of equipment connected to each utility meter and the number and size of diesel generators kilo-volt-ampere (kVA). DGs supplying power to fire safety equipment (mandatory as per government rules) are excluded from the study	Walk-through assessments with supervisor/manager/maintenance staff	In case of pumping systems, getting power rating details of submersible pumps was difficult. In some cases, mapping of utility meters to assets was not easily available except for meters that were supplying to large connected loads (e.g., pumps)
Electricity Consumption	Annual electricity bills of 3 years; usage or number of hours of operation of electrical equipment and appliances	Copies of monthly electricity bills obtained from supervisors for each utility meter. Also approached BESCOM with the account IDs of the meters to get billing data directly in case of data gaps; usage or number of hours of operation of each equipment and appliance was shared by supervisor	In most cases, electricity bills older than a year were unavailable. Most buildings do not maintain records of electricity bills. Where automatic water level controllers were used, getting data on hours of operation of pumps was challenging
Diesel Consumption	Number, size/capacity of DG set; annual or monthly use of diesel	Logs of diesel use shared by building supervisors and walk-through observations of meters on DG sets	DG logs were either missing or had incomplete data or unusable data in many cases. Multiple cases of nonfunctional meters were observed
Others	Size of rooftop solar installation (if any); any records of annual maintenance of equipment and appliances		In most buildings, there was a general lack of record keeping on electricity use, operational hours, maintenance of equipment, and troubleshooting (e.g., motor rewinding of pumps)

Source: WRI authors.

APPENDIX F.

Table F-1 | **Pump Types in Apartment Complexes and Their Applications**

PUMP TYPE	APPLICATION
Domestic Pumps	Used to pump either Cauvery water or Borewell water from the underground sump tank to overhead tank. Also includes pumps that pump treated water from the STP to the underground sump tank and then to overhead tanks providing flushing water in toilets. Included are also booster pumps to provide adequate water pressure to upper floors of high-rise apartment complexes.
Filtration Pumps	Pulls water from the pool, feeds it to the filtration system, and returns the filtered water into the pool. Also used to pump water through the water treatment plant to overhead tanks supplying treated water for domestic purposes.
Rainwater Harvesting Pumps	Used to pump harvested rainwater for various uses in the complex.
Other Pumps	Pumps used in water fountains and for pumping out excess storm water in basements.

Source: WRI authors.

APPENDIX G. SOME KEY DEFINITIONS AND RULES OF SUPPLY OF ELECTRICITY TO APARTMENT COMPLEXES IN BENGALURU

Components of the electricity bill

Sanctioned load: Sanctioned load is the total electricity load in kilowatts (kW) or horsepower (HP) that the consumer can use as per the agreement between the licensee (utility) and the consumer. In Bengaluru for new buildings, loads are assessed by the utility based on floor plans and certain rules of thumb that vary as per consumer category. For domestic consumers, 50 W/m^2 is fixed. The load sanctioned by the utility is, however, based on both "assessed" and "requested" (as per application form) load. The utility sanctions the higher of the two numbers. The complete sanctioned load may or may not be used by the consumer or exceed the limit. It is therefore important to also assess the connected load, which is the sum of the power rating of all equipment, appliances, and electrical assets connected to the electricity supply.

Maximum demand recorded: Maximum demand is defined as the average power supplied, measured in kilowatts or kilovolts, from the supply point to the consumer's premises. In a month, the maximum recorded power consumption of 30 minutes is used to determine the maximum demand for that month.

Fixed charges: Fixed charges are the charges imposed for the sanctioned load in kW. These are fixed by the utility and do not vary monthly based on monthly consumption. The billing is either for the sanctioned load or maximum demand recorded, whichever is higher.

Variable charges: Variable charges are paid for the power (in units or kWh) consumed by the consumer each month as per the slab rates. As per BESCOM, the slabs for LT-2a (residential category) are 31 to 100 units, 101 to 200 units, 201 to 300 units, 301 to 400 units, and above 400 units. Variable charges increase with slabs.

Supply rules for common services

- All new buildings with an assessed load of 25 kW or more or area of 600 m^2 or more must have space to accommodate a transformer. If the specified load is 100 kW or more, the applicant shall avail high tension supply for the building or complex. All apartment buildings had connected loads greater than 25 kW and had individual transformers on their premises (KPTCL n.d.).

- Electricity for common services in apartment buildings is billed under the domestic or LT-2 tariff category. BESCOM's tariff structure can also bill apartment buildings under an HT-4 (high tension- 4) category in case of high tension meters. As per BESCOM's last multi-year tariff petition filing, the HT-4 category has witnessed a negative growth rate. As of September 2018, BESCOM had only 222 consumers under the HT-4 category. In the 10 apartment buildings studied, no high tension meters were found in apartment buildings.

- In 2018, the Karnataka Regulatory Commission directed BESCOM to apply domestic tariffs for apartment buildings with sewage treatment plants after taking note of petitions made by several AOAs. At the same decision, BESCOM also clarified that if electricity usage for common services exceeds 25 percent of the total connected load, commercial tariffs will apply.[6]

APPENDIX H.

Table H1 | **Total Sanctioned Load, Average Annual Electricity Use, and Annual Electricity Costs for Common Services in the TEN Apartment Complexes**

APARTMENT COMPLEX	NUMBER OF APARTMENTS	TOTAL SANCTIONED LOAD (KW)	AVERAGE ANNUAL ELECTRICITY CONSUMPTION (KWH)	AVERAGE ANNUAL ELECTRICITY COST (INR)
A1	40	30	41,993	326,100
A2	96	40	26,898	207,387
A3	171	200	114,963	852,744
A4	190	125	125,770	877,329
A5	228	410	429,643	2,822,471
A6	387	661	426,907	3,263,317
A7	402	695	520,238	6,398,602
A8	482	530	728,268	4,475,772
A9	600	421	555,442	2,883,881
A10	1573	2249	2,242,422	15,975,213
Total	4169	5361	52,12,534	3,80,82,816

Source: WRI authors.

APPENDIX I.

Table I-1 | **Details of Common Area Assets in TEN Apartment Complexes**

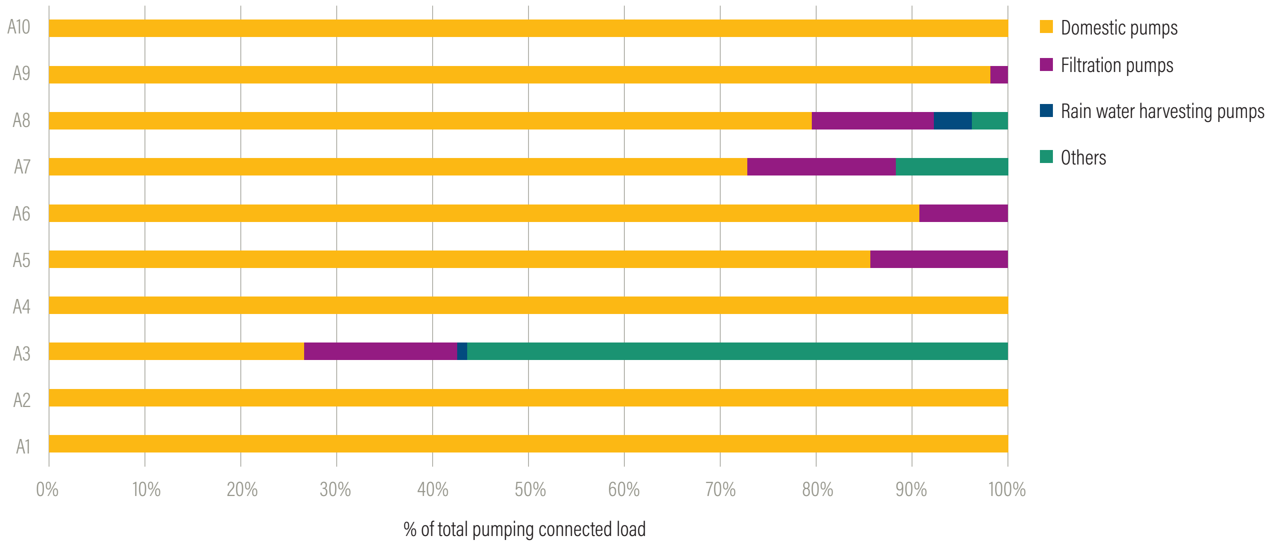
APARTMENT COMPLEX	LIGHTS	PUMPS	ELEVATORS	STP	HEATING	COOLING	MACHINERY	OTHERS
A1	LED bulbs and tube lights and TFLs (total n=58)	Domestic pumps (n=4)	Elevators (n=2)	×	×	Ceiling fans in (n=2)	×	×
A2	LED bulbs and LED tube lights, TFLs (total n=43)	Domestic pumps (n=3)	Elevators (n=2)	×	×	×	×	×
A3	LED bulbs, CFLs, TFLs, focus lights, PL fluorescent lamps (total n=259)	Domestic pumps, swimming pool filtration, rainwater harvesting, and storm water pumps (n=26)	Elevators (n=11)	×	Steam generator (n=2) and instant water heater (n=4) in sauna rooms	Table Fan (n=2), wall mounted fans (n=15), exhaust Fans (n=2)	Iron (n=1), treadmill (n=3) organic waste shredders (n=2)	×
A4	LED bulbs, CFLs, TFLs (total n=356)	Domestic pumps (n=5)	Elevators (n=5)	×	×	Table fans (n=4)	×	×
A5	LED bulbs, LED tube lights and focus lights (total n=1866)	Domestic pumps (n=8) and swimming pool filtration pump (n=3)	Elevators (n=6)	Present. Several types of motors and pumps (total n=19)	×	ACs (n=2), ceiling fans (n=2)	Organic waste shredder (n=1)	×
A6	LED bulbs, TFLs PL fluorescent lamps, metal halide lamps (total n= 908)	Domestic pumps (n=32), swimming pool filtration pump (n=8)	Elevators (n=18)	Present. Several types of motors and pumps (total n=24)	×	Ceiling fans (n=29)	×	TV
A7	LED bulbs, TFLs, PL fluorescent lamps, metal halide lamps (total n=1700)	Domestic pumps (n=15), swimming pool filtration pump (n=4), and fountain pump (n=4)	Elevators (n=12)	Present. STP pumps (n=3)	Steam generator (n=1) and instant water heater (n=1) in sauna rooms	ACs (n=8), ceiling fans (n=12)		Organic waste composter (n=1)
A8	LED bulbs and TFLs (n=2720)	Domestic pumps (n=47), swimming pool filtration and water treatment plant filtration pump (n=18), rainwater harvesting pump (n=5), and booster pumps (n=6)	Elevators (n=19)	Present. STP air blower (n=2)	×	Wall-mounted fans (n=12)	×	×
A9	CFLs, LED bulbs, TFLs, halogen lamps, dome light, (total n=1418)	Domestic pumps (n=37) and swimming pool filtration pump (n=1)	Elevators (n=18)	×	×	×	×	×
A10	Halogen lamps, TFLs, CFLs, LED bulbs (n=5602)	Domestic pumps (n=51)	Elevators (n=34)	Present. STP pumps (n=36)		AC (n=10) and fans (n=10)	Organic waste shredder (n=1)	Organic waste composter (n=1), computers (n=5), and printers (n=5)

Source: WRI authors.

APPENDIX J. INTER-APARTMENT VARIATIONS IN PUMP TYPES AND DIFFERENCES IN TOTAL CONNECTED LOAD OF PUMPS

- In the largest complexes A8, A9, and A10, pumping was 60, 56, and 35 percent, respectively, of the common area electricity load.
- A6, where pumps accounted for a majority of the common area connected load, had 40 pumps.
- In all apartment complexes except A3, load from domestic pumps was the largest. Domestic pumps included pumps used for not only pumping or supplying water for domestic use but also for pumping treated water from STP to tanks that supplied water for flushing toilets.
- Other than domestic pumps there were booster pumps, filtration pumps in swimming pools and water treatment plants, and pumps for the water fountain and for using harvested rainwater. These together accounted for 27 percent of pumping connected load.
- A8 had 76 pumps of many types. Each domestic pump had a standby pump.
- In A3, half the pumps were used for storm water management.
- In A5, filtration pumps in the swimming pool accounted for 15 percent of total pumping connected load.

Figure J-1 | **Percentage of Total Pumping Connected Load by Pump Type**



Source: WRI authors.

APPENDIX K .

Table K-1 | **Emissions in Ten Apartment Complexes Under Different Clean Energy Pathway Scenarios**

APARTMENT COMPLEX	BAU EMISSIONS (TCO2)	EE ONLY		RTS ONLY		EE+RTS SCENARIO 1		EE+RTS SCENARIO 2		REDUCTION IN RTS PLANT SIZE DUE TO EE MEASURES (TCO_2)
		EMISSIONS (TCO_2)	REDUCTION IN EMISSIONS (%)	EMISSIONS (TCO_2)	REDUCTION IN EMISSIONS (%)	EMISSIONS (TCO_2)	REDUCTION IN EMISSIONS (%)	EMISSIONS (TCO_2)	REDUCTION IN EMISSIONS (%)	
A1	34	28	20	-95	376	-102	397	0	100	79%
A2	22	19	13	-67	404	-69	415	0	100	78%
A3	94	82	13	-142	251	-154	264	0	100	65%
A4	103	98	5	-25	124	-29	129	0	100	23%
A5	352	342	3	173	51	162	54	173	51	0%
A6	350	327	7	-63	118	-86	125	0	100	21%
A7	427	390	9	-68	116	-105	125	0	100	21%
A8	597	575	4	0	100	-22	104	0	100	4%
A9	455	419	8	-54	112	-91	120	0	100	18%
A10	1,839	1,581	14	1,660	10	1,403	24	1,660	10	0%

Source: WRI authors.

APPENDIX L.

Table L-1 | **Analysis of the Influence of Primary and Secondary Stakeholders on Clean Energy Interventions for Common Services in Apartment Complexes**

	STAKEHOLDERS	DESCRIPTION AND INFLUENCE
Primary Stakeholders	Members of the Apartment Owners Association (apartment owners and residents)	■ All apartment owners are members of the AOA, and tenants are executive members. Members of the AOA weigh in on decisions that involve substantial expenditure for projects in the common areas. ■ Members of the AOAs play a key role in the decision-making process of implementing clean energy projects. This could mean □ consent to the use of maintenance budget or corpus fund toward project proposals put forward by the MC at the project discussion meetings; or □ approval of rules and regulations regarding reduction of end energy usage through changes in usage patterns (like drives to reduce lighting in common areas after a certain time of day) put forward by the MC.
	Management Committee of AOA	■ The members of the MC are the starting point for EE and RE measures to be implemented. The MC takes the initiative of sifting through and prioritizing issues relating to the maintenance of the apartment complex. ■ Once the MC has focused on a measure that it wishes to implement, it begins by making an informed assessment of the costs and benefits of the proposal. This involves gathering information regarding the measure, selecting potential vendors (in most cases at least 3), and assessing the budget required for implementation. If the budget required is significant (exceeds a certain amount stipulated in the AOAs bylaws) then the MC will need to convince residents to approve budgetary allocations during a general body meeting. ■ Additionally, the MC members can undertake initiatives that address usage patterns; for instance, drives to educate residents about switching off the lights and fans when they enter or exit the elevators.
	Facility Managers or Supervisors	■ Responsible for operation and maintenance of electrical appliances and utilities. These individuals can aid the implementation and effectiveness of RE/EE measures (by volunteering their technical know-how and agreeing to educate themselves about maintaining new EE/RE technology) or hinder that (by being uncooperative or providing incorrect analysis of equipment efficiency).
	EE Product Vendors and Service Providers	■ Can inform AOAs on what might be the suitable RE/EE measures and how to go about incorporating them. ■ Can also help with the actual execution of measures. ■ RESCOSs and ESCOs can suggest aggregating demand across apartment buildings in a neighborhood and achieve economies of scale.
Secondary Stakeholders	BBMP	■ Can influence current EE/RE trends through regulation and policy through incentives and tax breaks. ■ Penalizing non-implementers instead of rewarding implementers can deter uptake of EE or RE (as in the case of waste composting in Bengaluru).
	BESCOM	■ Responsible for providing electricity supply for common amenities in apartment complexes. ■ Can implement DSM measures for managing energy demand from common areas. ■ Also plays a key role in RTS approvals.
	Builders	■ Responsible for design and provision of facilities provided in new apartment complexes. ■ Because EE or RE measures could have an additional capital cost implication, many builders choose not to go with EE and RE products. Additionally, they may tend to avoid the burden associated with the bureaucratic processes of obtaining approvals and subsidies for RE interventions. ■ However, an emerging trend is to brand new developments with a green tag, which acts as a unique selling point. Hence, builders are becoming attracted to using RE or EE technology to fetch higher sales prices for their apartments.
	Financial Institutions or Banks	■ Can help finance initial investments required for clean energy measures that cannot be met through funds available to AOAs, thus removing the initial capital investment barriers especially associated with RE.

Source: WRI authors.

ENDNOTES

1. Final energy use is defined as the total energy consumed by end users, such as buildings, industry, agriculture, etc. The term does not include energy used in transformation, distribution, and transmission. Energy-related carbon dioxide emissions refer to emissions of carbon dioxide from production of energy due to combustion of coal in thermal power plants or in other sectors (like industries) and from burning of other fossil fuels.

2. Bengaluru's municipality, Bruhat Bengaluru Mahanagara Palike (BBMP) defines a high-rise building as one with a height of 15 meters and above (roughly ground floor + four floors) in the building bylaws of 2003.

3. Motor rewinding is the process of repairing electric motors when the winding fails. It is the process of unwinding the old rotor and stator windings and replacing it with new ones. The process helps increase the life of the motor-based equipment.

4. Competing uses include private access to roofs for some residents or to all for leisure for accessing water storage tanks.

5. In 2018, the Karnataka Regulatory Commission (KERC), directed BESCOM to apply domestic tariffs for apartment buildings with sewage treatment plants after taking note of petitions made by several AOAs. In the same decision, BESCOM clarified that if electricity usage for common services exceeds 25 percent of the total connected load, commercial tariffs will apply. At the time of the writing of this paper, in its tariff petition to KERC in May 2019, BESCOM had proposed that "clubhouses/gym/sport facilities of the apartment complexes where nonresident members or guests of residents of the apartment are allowed or outsiders who are allowed on rental basis, such clubhouses/gym/sport facilities of the apartment complexes shall be classified under commercial tariff category."

6. "BAF Launches New Initiative for Better Bengaluru". Read more at https://www.deccanherald.com/city/baf-launches-new-initiative.

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ABOUT THE KNOWLEDGE PRODUCT SERIES

The consensus to hold global warming to below 2°C requires drastic emission cuts, with significant efforts required on energy transformation across key geographies, including India. The Indian government has issued a series of renewable energy support policies and ambitious targets, and this has seen traction among state governments. These are "push" efforts, aimed at primarily increasing the supply of renewables. However, several barriers (technical, financial, information, regulatory, and policy) continue to restrict and limit both the integration of these technologies in the grid and their adoption by end users.

WRI's Green Power Market Development Group initiative seeks to draw attention to and focus on the complementary "pull" side; focusing on groups of end consumers looking for clean energy solutions that are aggregated to enjoy the economies of scale and therefore come with lower project and transaction costs. We worked with key stakeholders in these natural aggregators to procure renewable energy and energy efficiency products and services and to put them on GHG emission reduction pathways.

This working paper captures our experiences from our pilot efforts with aggregating demand for apartment complexes. By focusing on the end-user demand side, and by focusing on energy-intensive consumers, we expect to multiply the benefits of the supply-side efforts of the Indian government. This paper seeks to add to the growing knowledge of how clean energy adoption can help address climate change. We believe that sustained efforts with energy-intensive end consumers to scale clean energy adoption can accelerate ambitious transformation toward a low-carbon economy.

ABOUT WRI INDIA

WRI India is a research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure that our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

ABOUT TIDE

Technology Informatics Design Endeavour (TIDE) (www.tide-india.org) is a development organization that leverages technology for conserving the environment, creating livelihoods, and addressing societal issues. TIDE's work encompasses energy access and biomass-based cooking, renewable energy, energy efficiency (RE and EE), and environment conservation and innovative livelihoods for rural women. Since inception, we have developed, adapted, and transferred technology options like improved cook stoves, biogas, biomass gasification, biomass briquetting, and energy audits. Our work aligns with Sustainable Development Goals of the United Nations.

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