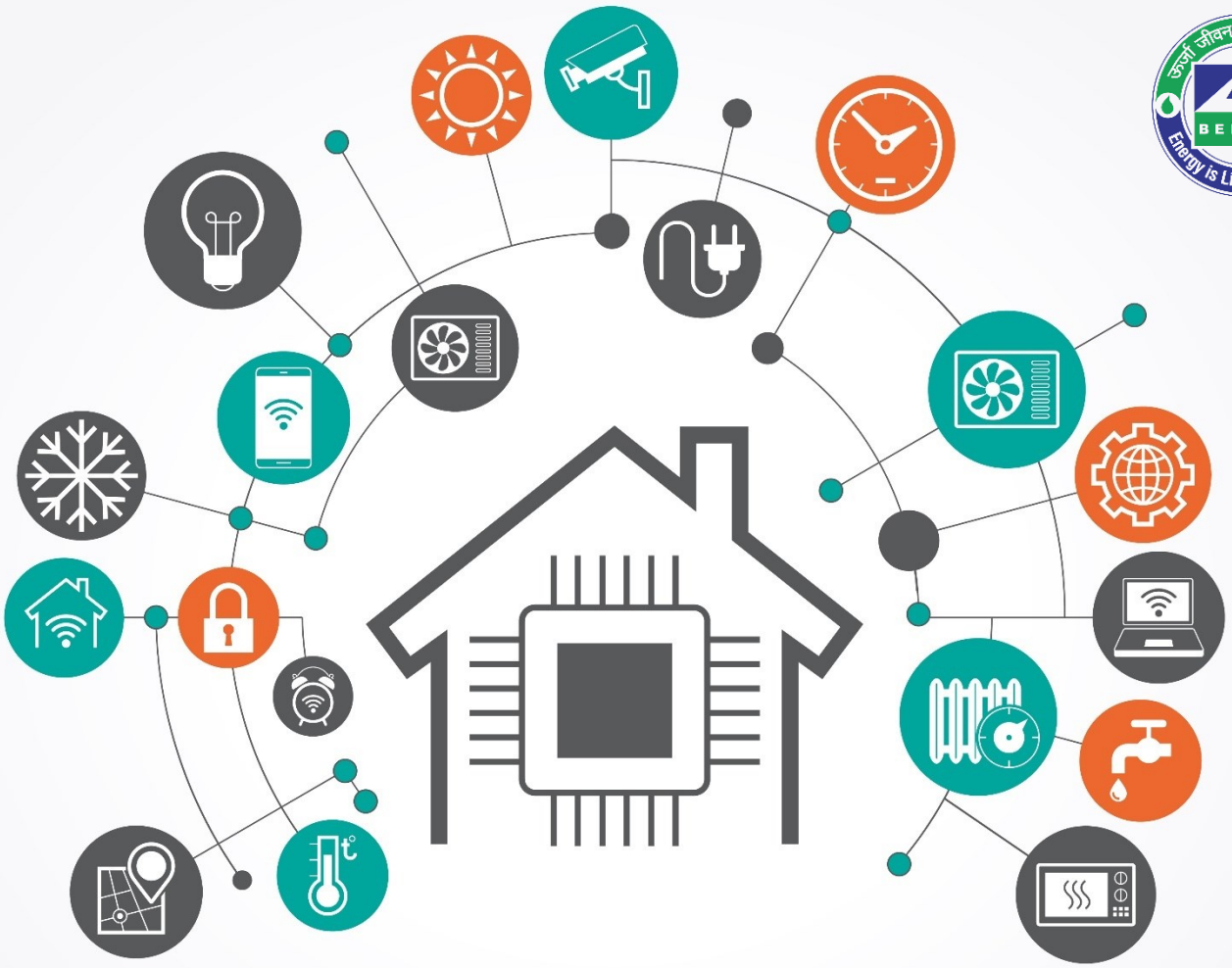

Smart Home Program - Technology Assessment Study and Pilot Design

Report on National Policy Roadmap for Home Automation Technologies for Residential Energy Efficiency

July 2021

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DEUTSCHE ZUSAMMENARBEIT

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Version

July 2021
New Delhi

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महानिदेशक

ABHAY BAKRE, IRSEE
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सत्यमेव जयते

ऊर्जा दक्षता ब्यूरो
(भारत सरकार, विद्युत मंत्रालय)

BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

Message

The concept of smart home is in existence for many decades; however, it has gained further importance in present scenario due to increase in demand for comfort and convenience (with growth of disposable income), increased dependence on appliances, increase in per capita electricity consumption and availability of rooftop solar PV and EV for potential onsite generation and storage respectively.

Alongside these drivers at consumer end; technology advancement in the form of availability of high speed computing devices (smart phones) and affordable internet data, reduction in size of IoT devices / sensors and by shifting sophisticated computing functions to cloud and development of complex algorithms to control systems as per user requirement and preference (using Artificial Intelligence) has provided fresh push to demand of smart home product and services. The need of utility-based demand response programs to match the variable consumer demand (due to use of diverse appliances) with dynamic electricity supply (due to penetration of renewable energy in grid) is gradually making the smart home solutions a must have product/service in every home, to make it demand response ready.

There are several challenges to adoption of smart home devices in India and majority of them include absence of interoperability standards / protocols, limited regulations on data privacy / cyber security, lack of awareness among consumers about energy saving potential, and functionality of smart home devices (to provide energy efficiency and DR benefits) in absence of defined minimum capabilities. In addition to this policy is required to qualify a dwelling into smart dwelling so that it can effectively participate in a demand response programme.

To explore, understand and exploit the true potential of smart home ecosystem, to identify barriers, drivers, challenges and opportunities and to estimate future growth potential in the country, Bureau of Energy Efficiency (BEE) along with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, India) instituted a study through Deloitte Touche Tohmatsu India LLP (Deloitte) on smart home program technology assessment and pilot design. It is expected that the study outcome will feed into development of guidelines and regulations to further facilitate the growth of the smart homes market in India along with the benefits on optimization of energy consumption in the residential sector that may also contribute to the NDC commitments of India.

This report provides a deeper insight into the home automation space along with recommendations for possible policy and regulatory interventions. I congratulate colleagues from Bureau, GIZ India and Deloitte for this interesting work.

Abhay Bakre

(Abhay Bakre)

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Acknowledgement

The Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India has been engaged in several initiatives to design and implement energy efficiency programs. To facilitate assess of the smart home automation technology(ies), BEE in association with Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) India has instituted study entitled "Smart Home Program – Technology assessment study and pilot design" under the grid integration of renewable energy and demand side energy efficiency project.

The purpose of this study is to essentially understand and prioritize appropriate technologies for India that are most feasible for automating control at household / residential levels with systems and appliances to increase efficient use of energy. Findings of this study will feed the design of initial demonstration or test bed for Smart Homes.

In this context, BEE and GIZ, with support from Deloitte Touche Tohmatsu India LLP has prepared a report on the National Policy Roadmap for Home Automation Technologies for Residential Energy Efficiency. The team extends its profound thanks to Mr. Abhay Bakre, Director General, BEE for his leadership and guidance during the execution of the assignment. The team recognizes and extends its sincere gratitude to Mr. R.K. Rai, Secretary, BEE, for his guidance and entrusting us with this important study.

BEE acknowledges the guidance provided by Mr. S. Vikash Ranjan, Programme Manager, GIZ GmbH. The team appreciates Mr. Abdullah Nisar Siddiqui, Technical Expert, GIZ GmbH, Ms. Akanksha Krishan, Sector Expert, BEE and Mr. Chawan Vijay Kumar, GIZ GmbH for their constant support and valuable inputs. BEE also acknowledges the support provided by sector experts in stakeholders consultation events organized on 19th June and 9th October 2020.

Saurabh Diddi
Director

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1. Introduction

1.1 Background

One of the most challenging issues faced by India in the 21st century is to maintain the momentum of its economic growth without compromising the ambitions related to energy security and environmental sustainability. India's energy challenge is unique with a distinct dichotomy of being the third-largest energy consumer with a per capita consumption nearly a third of the global average.

India's developmental challenge becomes further convoluted with priority towards 24 X 7 electricity access to its 1.3 billion citizens. Other domestic initiatives like 'Make in India', and the 'National Housing Mission' (NHM) are also expected to further increase the demand for energy in industrial and buildings sectors. In 2018-19, the primary energy demand in India increased[1] by 4.7 % over the previous year, much higher than the average global increase, and around 50 % higher than that of the emerging economies.

Notwithstanding this increase, India lags significantly in energy usage compared to other emerging economies as 53 % of our population could not access clean cooking in 2017 when compared to 30 % for China, 4 % for Brazil and less than 1 % for Malaysia. India's Human Development Index (HDI) at present stands at 0.647[2] which places it above the average for other South Asian countries (0.642). However, for inequality adjusted HDI (IHDI), India's position drops by one position to 130, losing nearly half the progress. India aspires to achieve an HDI value of 0.8 in the coming years which may result in per capita energy consumption to 400 % of current levels. The Economic survey of India quotes another study which states that with 2.5 times increase in per capita energy consumption, India's per capita GDP will increase by US$ 5000 (at 2010 prices).

It is widely recognized that relying on capacity additions alone to meet the expected growth in energy demand will not be sustainable – both financially as well as environmentally[3]. Energy efficiency thus has a critical role to play in enabling India to fulfil its economic and sustainability aspirations simultaneously.

Energy use in buildings

In 2018-19, buildings in residential sectors consumed about 24.2[4] % of India's electrical energy – primarily for HVAC, lighting and ceiling fan. Sector wise electricity consumption for FY 2018-19 is provided in adjacent figure.

Between 2009 and 2019, electricity demand in the residential sector increased at a rate of 7.5 % per annum, slightly higher than the rate of increase total electricity demand of 7.3% during the same period. Growth trend of electricity demand of residential sector is provided in figure below

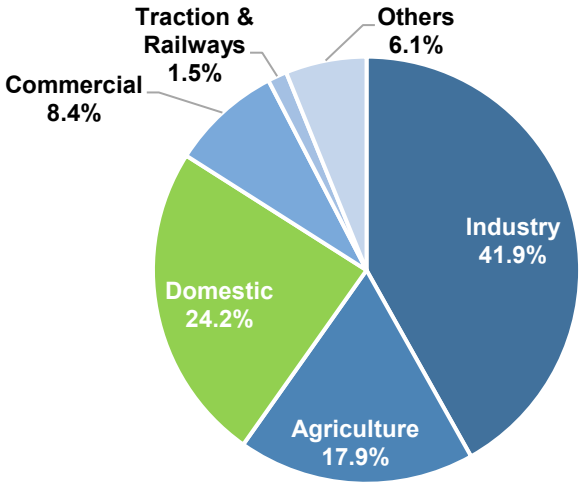
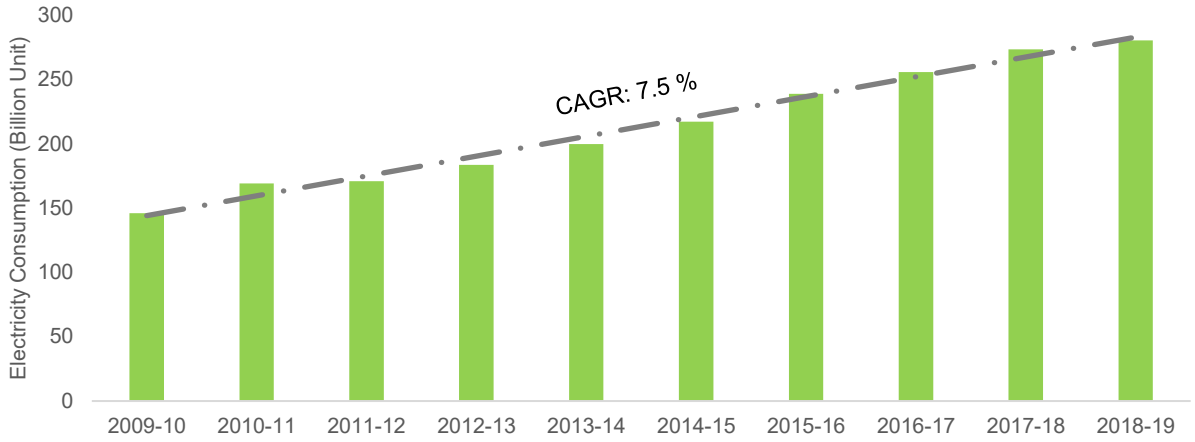


Figure 1 Sector wise electricity consumption in FY 2018-19, Source: Energy Statistics 2020, MOSPI

[1] Source: Energy statistics 2020, Ministry of Statistics and Programme Implementation
[2] Source: UNDP 2019: Global HDI Report
[3] Source: India's NDC to the United Nations Framework Convention on Climate Change / Paris Agreement
[4] Source: Energy statistics 2020, Ministry of Statistics and Programme Implementation



The key factors behind this growth were rapid economic growth, rising per capita income, growing population, and increased urbanization rate resulting in higher appliance ownership. With urbanization this trend is expected to continue at least for the next decade. The electricity access having been provided to millions of new users in the past 4 years, appliance ownership, and thus the related energy demand is expected to rise further with household electricity consumption increasing 6 - 8 times[5] by 2047 as per NITI Aayog's estimates.

It is therefore imperative to both widen and tighten appliance efficiency standards to reduce energy demand from the buildings sector. Considering that household appliances generally have a much shorter life as compared to buildings and industrial machinery / equipment, strengthening & regimenting standards and protocols for appliances and promoting energy efficiency in the residential sector offers a low-hanging fruit for advancing energy efficiency in India.

Energy Efficiency in buildings

With rapid urbanisation, construction of new buildings is gaining significant importance as more than 300 million rural & semi-urban residents are expected to migrate to towns and cities in India by 2030. With schemes like Pradhan Mantri Awas Yojna (PMAY), alongside private and municipal construction, large proportion of this population is expected to live in buildings which have not been constructed yet. Implementation of energy efficiency measures can help in reducing energy demand of residential sector anywhere between 30 to 40 % for new construction as well retrofit in the existing building stock. The sector thus offers a significant potential to prevent an inefficient capital stock from being locked-in for the long term.

In view of this, several programs have been proposed for improving the energy-efficiency of both the existing as well as new buildings. At present, India boasts of a portfolio of over 3,000 registered green buildings projects (second largest in the world) covering about 2.68 billion sq. ft of which 600 buildings are certified and fully functional.

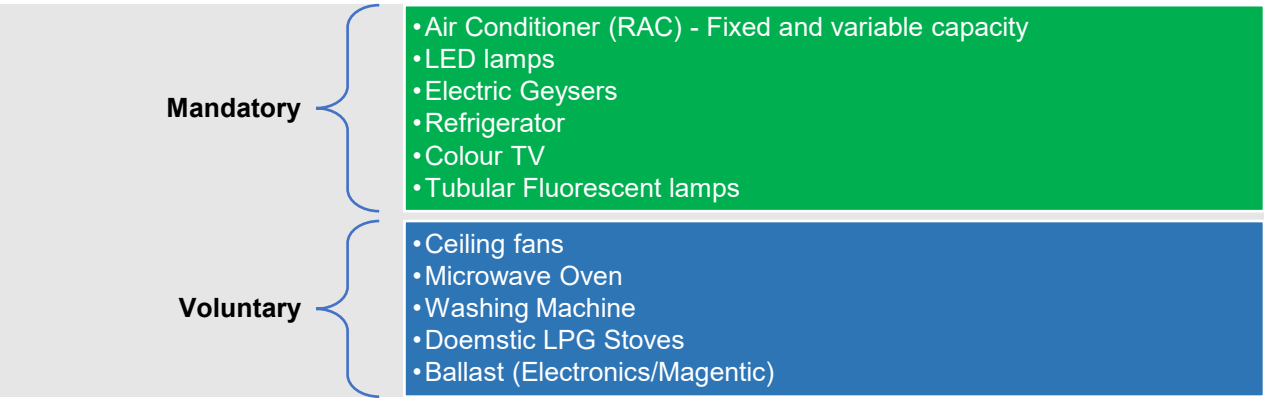
BEE developed Energy Conservation Building Code (ECBC and ECBC-R), for commercial and residential buildings. The code recommends a minimum level for efficient use of energy. ECBC for the residential sector named as the 'Eco Niwas Samhita, Part – I sets a minimum building envelope performance standard to limit heat gains / loss and ensuring adequate natural ventilation and daylighting.

To promote energy efficiency in existing homes and buildings, energy efficiency star label program has been developed for residential sector. The objective of the labelling program is to make energy performance of a home an instrument of comparison while deciding over the home prices in the future. "Design

[5] Source: http://iess2047.gov.in/pathways

Guidelines" for energy-efficient multi-storied residential buildings have also been launched. BEE also has a voluntary buildings star rating system for commercial buildings based on the actual specific energy usage in kWh/ sq.m /year which now covers over 261 commercial buildings[6] – including office buildings (198), BPOs (48), hospitals (13), and shopping malls (2).

To improve energy efficiency of domestic, commercial and industrial appliances and energy consuming equipment, BEE has implemented Standards & Labelling (S&L) programme. The standards ensure that the worst performing products are removed from the market, while labels encourage consumers to purchase increasingly more efficient products. The S & L program covers 26 appliance categories, 10 under mandatory scheme and 16 under voluntary scheme. Major home appliances covered under S & L program include:



The Smart Cities Mission, covering 100 selected smart cities across the country is another such initiative of the government to reduce building energy consumption. The mission was launched in 2015 to promote the adoption of 'smart solutions' for environmental sustainability including resource efficiency and energy optimization. The projects under the mission include a mix of innovative solutions for sustainable urban development including Smart Grids, Green Buildings, Smart Public Transport Systems, Public Information Systems, Smart Water Management, and Waste Management etc. While substantial work on enhancing energy efficiency in the sector has been taken up, their long-term success in generating momentum for the adoption of energy efficiency remains to be ascertained.

Smart home

A smart home is a residence that uses internet-connected devices to enable the remote monitoring and management of appliances and systems, such as lighting and heating. Smart home technology, also often referred to as home automation, provides homeowners security, comfort, convenience and energy efficiency by allowing them to control smart devices, often by a smart home app on their smartphone or other networked device. A part of the internet of things (IoT), smart home systems and devices often operate together, sharing consumer usage data among themselves and automating actions based on the homeowners' preferences, external environment, and AI and machine learning based control.

The concept of smart energy home is in existence for many decades; however, it has become more relevant in current scenario due to increase in demand for comfort and convenience (with growth of disposal income), increased dependence on appliances, increase in per capita electricity consumption and availability of rooftop solar PV and EV for potential onsite generation and storage respectively.

Along with the mentioned drivers at consumer end, technology advancement, in form of availability of high speed computing devices (smart phone) and internet (at affordable rate), reduction in size of IoT devices/sensors (by shifting the complex computing functions to cloud based computing) and development

[6] Source: A report on Impact Assessment of Energy Efficiency Measures for the year 2018 - 19, Bureau of Energy Efficiency

of complex algorithms (to control systems as per user requirement and preference using Artificial Intelligence) have provided a new impetus to demand of smart energy home product and services.

Also, the need of utility-based demand response program to match the variable consumer demand (due to use of diverse appliances) with intermittent electricity supply (due to penetration of renewable energy in grid) is gradually making the smart energy home solutions a must have product/service in every home to make it demand response ready.

To manage the energy use in a home, to make best use of above-mentioned opportunities and for supporting power utilities in minimizing the demand supply gap, there is need of Smart Home Energy Management System (SHEMS). SHEMS can be defined [7]as the combination of a service and devices that are designed to work together to deliver occupancy-based optimization of energy use. SHEMS[8] consist of hardware and software, which are linked and integrated to, monitor energy usage, provide feedback on energy consumption, provide enhanced control (provide remote access) and automation over appliances. SHEMS can deliver a range of services and benefits to households, which includes:

- Energy management (energy efficiency)
- Demand response (contribute to regulating energy demand)
- Electricity generation, storage and delivery to the grid
- Comfort and convenience

For energy efficiency improvement in residential sector, home is the smallest dwelling unit for the bottom-up approach. Interventions at the individual unit can contribute to the larger goal that the society and the government wishes to achieve in the longer run. The global experience indicates that with the support of progressive legal, regulatory and policy frameworks in the electricity sector, smart homes concept offers a significant opportunity to optimise energy consumption in the building sector, save on energy costs, and avoid costly capital investment towards augmentation of capacity for electricity generation, transmission and distribution.

In India, the present concept of smart homes is at an early stage that brings the significant untapped potential for achieving energy efficiency gains through residential sector. Therefore, improving energy efficiency, dynamic optimization of energy consumption, and integration of smart home with the overall smartness of the electrical distribution network becomes the need of the hour.

1.2 About project

Background

With a view of increasing electricity demand and need of managing it, an effort for energy conservation was initiated by Government of India with introduction of Energy Conservation Act published in the Gazette of India in October 2001. Bureau of Energy Efficiency (BEE) was instituted in 2002, to implement EC Act. Further first version of Energy Conservation building Code was launched by Government of India in 2007. BEE has also launched the Star rating of commercial buildings scheme in India in 2009.

EC Act was amended in 2010 with further update of Commercial ECBC in 2017. After this update, ECBC (commercial) was mandated for all commercial buildings falling in its purview (Connected load ≥100 kW or contract demand ≥120 kVA). The various initiatives and programmes undertaken by various ministries and institutions in India for buildings sector are presented in Figure below

[7] Energy star
[8] Sustainable Now

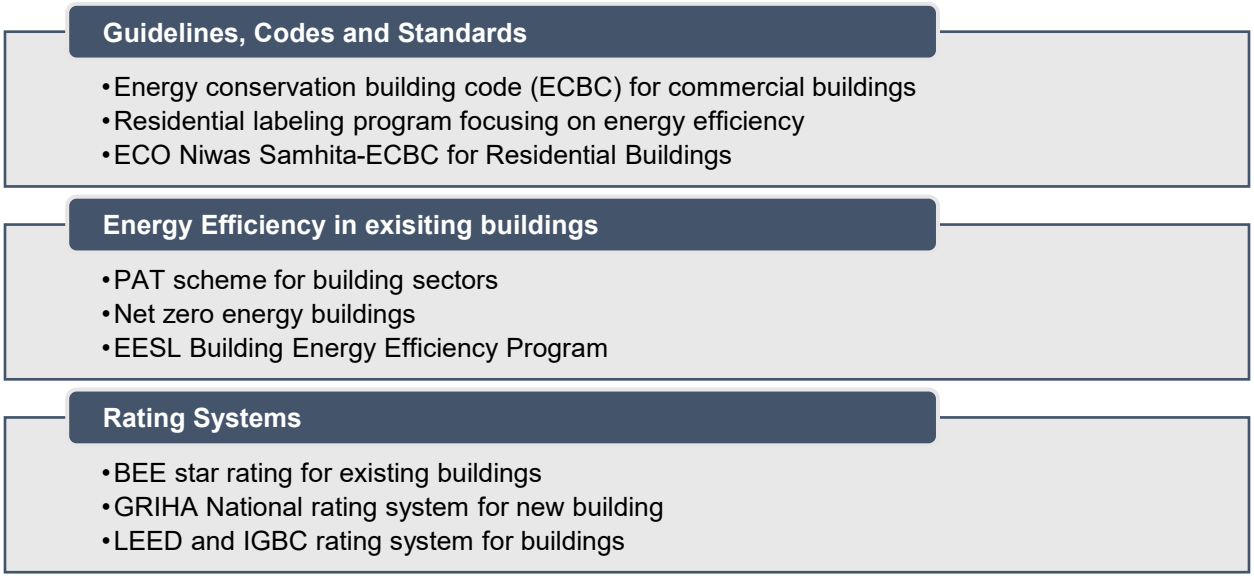


Figure 2 Programme initiatives in building sector

Bureau of Energy Efficiency is developing and implementing policies for increasing energy efficiency in the building sector. In a parallel movement, the Government of India has launched measures to augment capacity of grids to anticipate and control energy demand through digital, remotely controlled technologies and to increase penetration of renewable energy sources in power generation by installing 175 GW capacity by 2022. As per India's NDC commitment, by 2030, about 40 percent cumulative electric power installed capacity is expected to be based on non-fossil fuel-based energy resources.

At some point in future, this generation of building energy efficiency policies, renewable energy and, smart supply and transmission infrastructure (beginning to be built) will have to be seamlessly integrated for attaining maximum energy use optimization in building sector. Essentially building energy efficiency polices will have to mandate buildings and building technologies to be designed for participation in a dynamic energy supply and management framework.

Purpose of this study

The purpose of this study is to understand and prioritize technologies for India that are feasible for automating control of household envelope and appliances to increase efficient use of energy. Outcome of this study will feed into development of national roadmap for promotion of smart home concept to improve building energy efficiency and to make Indian homes ready for large scale implementation of demand response program(s). The assignment will also feed into the design of initial demonstration project or test bed for Smart Homes. Objective of the assignment and scope of work is provided in figure below:

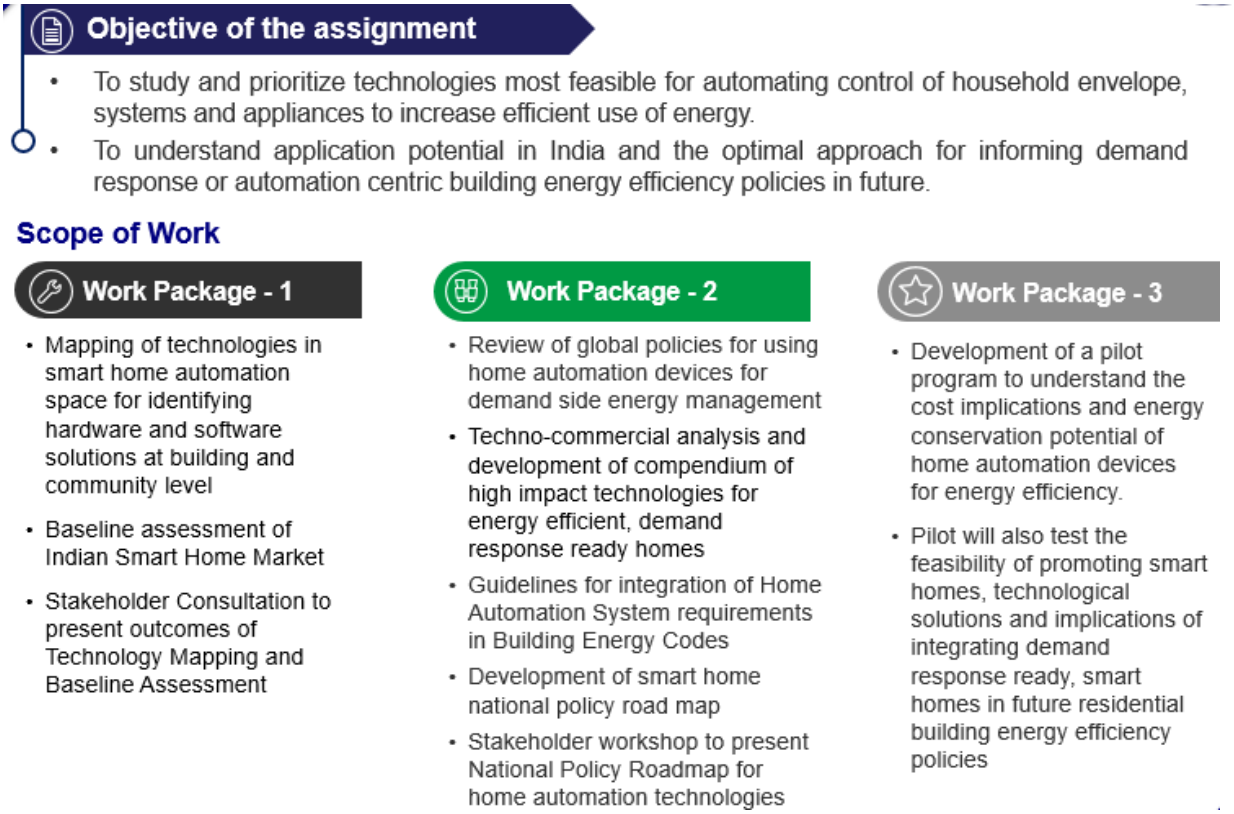


Figure 3 List of project activities

1.3 Overview of chapters

This report provides summary of outcome of all deliverables of this assignment. The report has five chapters. **Chapter one** provides introduction of project and the rationale behind instituting this study.

Chapter two introduces smart home concept and provides technology trends of smart home devices, mapping of hardware and software elements of smart home, energy saving potential and factor affecting energy savings.

Chapter three provides results of baseline assessment of Indian smart home market conducted as part of this study. The chapter provides current market size, segmentation, drivers, barriers, opportunities and market forecast till 2030.

Chapter four provides brief review of global policies, related to smart home and demand response, which are employed globally to overcome some of the barriers to adoption of smart home devices identified in previous chapter.

Chapter five provides list of potential recommendations, national policy road map and implementation framework to overcome barriers to adoption of smart home devices in India. Techno-commercial analysis of smart home devices and retrofits is provided in **annexure 1.**

2. Mapping of smart home technologies

2.1 Smart home concept

In generic terms, a smart home is a residence that has a system (composed of a range of smart home appliances) or several systems that are connected to a network and can be controlled remotely or automated. Smart home solutions or systems enables the control and automation of lighting, heating, ventilation, air conditioning, and security, as well as home appliances such as washer/dryers, ovens, refrigerators/freezers and home electronics such as TVs and streaming devices. Smart homes can deliver a range of services and benefits to households which includes:

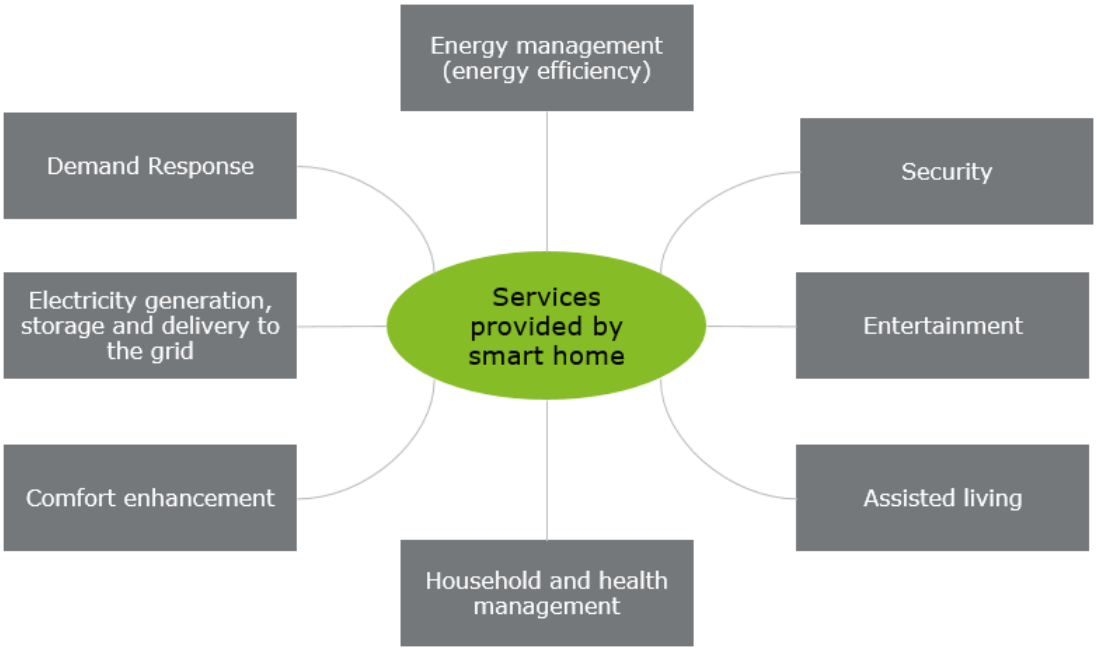


Figure 4 Services provided by smart home

There is no standard set-up for a smart home. The types of devices and the system or systems within a smart home vary depending on the needs and desires of the household and can change over time as devices are removed from or added to the system. Illustration of a smart home provided in figure below followed by a brief about working of a typical smart home automation system.

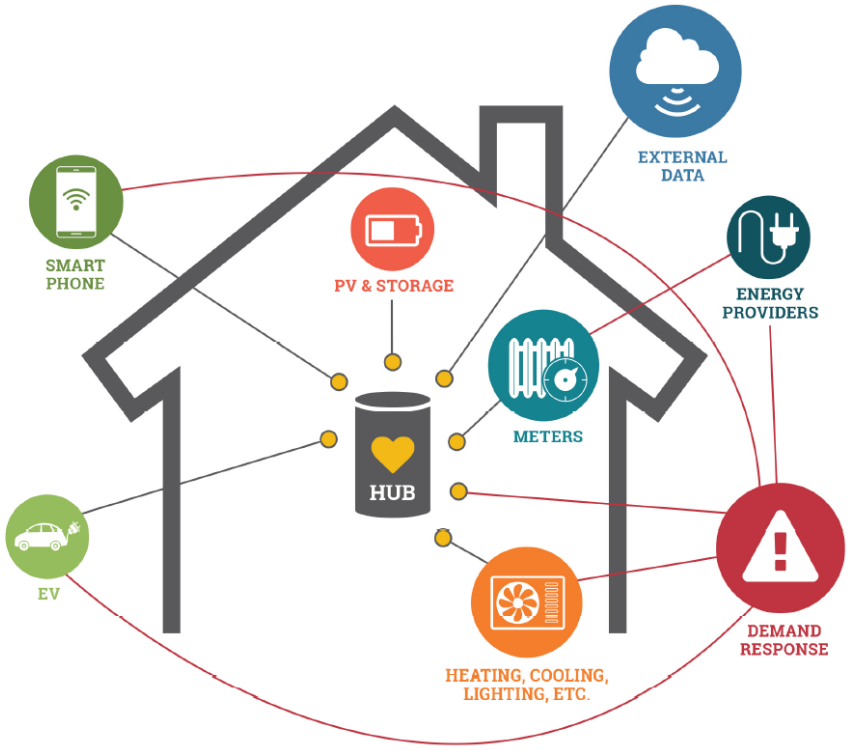


Figure 5 Illustration of smart home energy management system (SHEMS). Source: Intelligent Efficiency: Case study of barriers and solutions - Smart Homes

In the set up mentioned above, each component or element of the smart home system are connected to a central server through a network. Brief about associated elements and working of smart home automation system is provided below:

- Central hub is connected to:
    - Energy providers (both utility as well as in house generation). In case of utility the hub is connected to energy meter and for in house generation, the monitoring and controlling system of the generator is connected to hub.
    - Energy consuming appliances such as lighting, HVAC system, refrigerator, electric vehicle, washing machine, television, water heaters etc.
    - Components of house that have bearing of energy consumption such as curtains, windows, doors, thermostats etc.
    - User interface devices like smart phone and monitors
    - Infotainment devices such as AV (audio visual) systems, ChatBots etc.
    - Home security system
    - Other devices such as home and health management systems

- All connected devices generally have two-way communication and have compatible hardware and software to:
    - sense the physical conditions,
    - understand commands of users
    - capability to act on sensor inputs, user instructions and preference
    - capability to store the data regarding event, incidents/preference and use analytics to generate sensible learning from gathered data

- For demand response the utility generally interacts with energy meter to signal peak incident, collect user consumption data for estimation of incentives and for demand forecasting. Once the peak incident is reported, the energy meters interact with smart hub or HEMS and it responds by altering the energy consumption of home by either by switching of user defined non-preferential load or by changing the operating parameters such as room temperature, lighting intensity etc.

- Generic working schematics or flow of activities of smart home system is provided below:

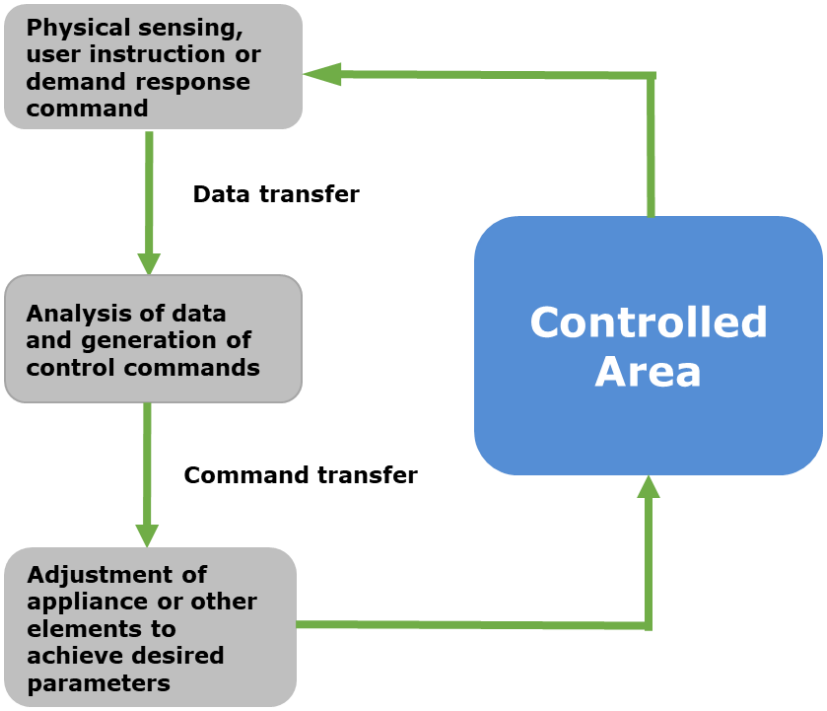


Figure 6 Working of smart home system

- In smart home automation system, energy and cost saving and demand response is achieved by

    - Preventing idle running of energy consuming device
    - Optimization of adjustable building envelope elements
    - Optimization of operating parameters to match user preference
    - Shifting the operation of non-essential energy consuming device to off peak time
    - Making use of renewable energy generation source, whenever available to meet the energy demand
    - Storage the surplus renewable energy to offset peak demand

2.2 Need of smart home

Energy demand is increasing worldwide due to rapid economic growth and widespread access to energy resources. In India, buildings sector (residential and commercial) constitutes 32.6% of total electricity consumption in India. Building sector consumes about 377 billion units (BU), as per the 2018-19 figures of the Ministry of Statistics and Programme Implementation, Government of India. If current scenario continues, electricity demand will rise from 377 BU per year to 4,697 BU per year and buildings will demand 55% of total electricity generated by 2047. Electricity demand in residential and commercial buildings sectors is predicted to rise by 5 folds and 3 folds respectively by 2032[9].

[9] Source: A report on Impact Assessment of Energy Efficiency Measures for the year 2018 - 19, Bureau of Energy Efficiency

Utilities are facing a challenge in meeting the peak demand of residential energy due to the heavy expenses that are incurred in the infrastructure setup of peaking demand generating source as well as transmission and distribution infrastructure. The addition of renewable energy generating sources to the electricity mix has also contributed to intermittence in the availability of energy. In this scenario, demand response can be used by electric utility companies to reduce or shift energy consumption from peak hours of the day, when the demand for electricity is the greatest to leaner demand periods.

The smart home devices facilitate the utilities in engaging with the residential electricity consumers to implement demand response by putting in place required infrastructure to link utility servers with individual dwelling through smart devices. Going forward, this link and capability of controlling appliances from anywhere (by consumer or utility) can play an important role in improving the peak load management in utilities.

2.3 Technology trends in major regions of the globe

The developments in the technology that resulted in low powered, low cost computing devices along with cheaper internet data access are the two principal drivers behind adoption of connect devices (Smart Homes) at almost every level of society and residential sector has also started witnessing their penetration. Major factors responsible for faster adoption of IoT based smart home devices include:

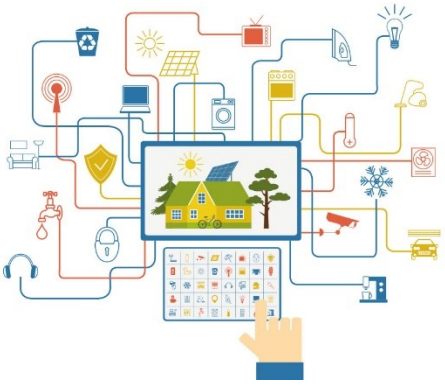
- Accessibility to cloud computing and storage,
- Distributed intelligence
- Easy availability of Internet of Things (IoT) technology-based devices
- Growing internet penetration
- Robust and stable communication network infrastructure
- Liquidity in market and increased disposable income among people
- Sophisticated lifestyle resulting in continuous demand for smart products
- Availability of Do It Yourself (DIY) kits that are affordable through e-commerce channels. These kits include smart sensors that can be integrated to home appliances increasing their versatility and usage over internet

In addition to this, penetration of roof-top solar, net metering and electric vehicles is destined to play a significant role in the smart home by converging into a micro grid. Electric vehicles would not only provide a clean and efficient mode of transportation but would act as virtual power plant which after integrating with residential setup could further strengthen the stability of grid during peak power demand. The smart home ecosystem comprises of a mix of hardware, software and communication protocols; technology trends about few of them are presented below:

1. Entry level devices - Voice controlled speakers, routers, Set-Top Boxes (STB)

Smart gadgets have entered homes through devices like routers, set-top boxes and voice-controlled speakers. Using connectivity, communication and entertainment to introduce the concept of Smart devices to householders, the industry players have a niche platform to establish a dedicated market for their products and related services. The smart hubs which integrate communication between various smart devices installed are seen to be eventually merging into Wi-Fi routers (Samsung SmartThings V3) or set-top boxes (Cox Communications and Comcast).

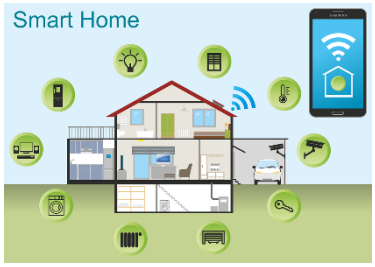
2. Smart homes as a service



Smart homes are being sought to be provided as a service that is driven by utilities, telecoms and cable network providers. Smart home technology is more about the overall system – the services provided – rather than the connected devices themselves. Consumers want the benefits without having to master the technical details. That's why the next smart home frontier will be Smart Home as a Service (SHaaS), provided and managed by a third-party service provider.

Cable companies and ISPs already have a box in the home and an existing relationship with the household. Utility and security companies also have this connection and are eagerly moving into this space. Large retailers like Walmart, Home Depot, Costco, etc. are looking to provide the entire suite of services and system, from the technology selection and installation to the day-to-day maintenance, to ensuring security and facilitating service updates and the addition of new services. By bundling the smart home services together, this single provider can overcome the challenge of various emerging technologies and, maybe even more importantly, can provide the consumer with a single platform that can manage the entire suite of home services with a common user interface.

3. Standard fitment



Home automation is being conceived as a standard fitment in new homes. So, it can be expected that soon the community of builders will be keen on popularising this component in the upcoming residential construction as standard fitment to improve comfort and provide energy savings.

4. Value added services

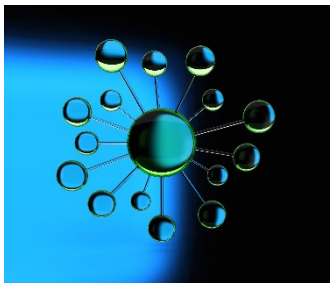
Value added services including Fault Detection and Diagnostics, maintenance and warranty will be an integral part of these standard home automation fitments. Recently it was announced that Grid4C is providing its AI software solution for integration with Itron's Riva IoT smart metering solution.

AI Grid Edge solutions will provide utilities with real-time predictions and actionable insights for their operations and customer-facing applications. This technology enables home energy management at the appliance level, and the prediction, detection, and diagnostics of faults for grid assets and home appliances, to improve operational planning, reduce peak demand, increase energy savings, etc.

5. Smart devices

Smart devices such as speakers, lights, water heaters, AC, washing machine, can be either connected to the internet or can take commands locally. All these devices can communicate, send information, and take commands. This is made reality by the Internet of Things (IoT), and it's a key component of smart homes. These devices make activities, like setting up a lamp to turn on and off as per consumer preference is simple and relatively inexpensive. It is possible to interconnect devices and use single App for control and monitoring.

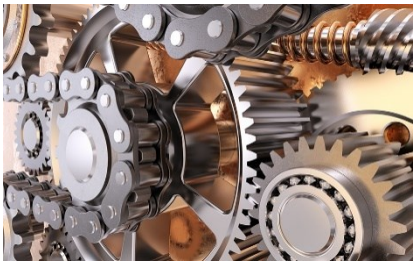
6. Smart home aggregators



The concept of Smart homes facilitates the utilities to bring in demand response and engage with the residential electricity consumers to implement demand response. Aggregators in the building space environment, that include-dedicated organisations, builders and technology promoters, enable the needed bridge between utilities and consumers to simplify the implementation of demand response.

In the United States of America, companies have been supporting individual buyers and organizations in procuring quality conservation products at affordable prices. Aggregators provide incentive fulfillment services to utility clients throughout the US. They have been delivering innovative, high-quality programs that provide real, measurable savings. Aggregators assist people in these efforts by offering high quality conservation products and services at affordable prices while communicating practical, objective information.

7. Standardization and interoperability



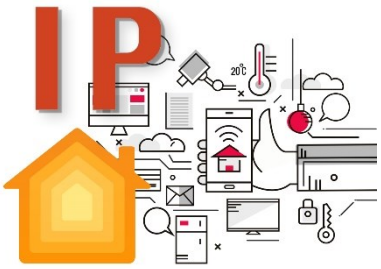
Standardisation and interoperability are vital to ensuring the success and security of IoT solutions in the home automation sector.

The Open Connectivity Foundation (OFC) members and ATIS[10] have collaborated to develop an open source implementation of an interworking proxy as a pivotal step to facilitate seamless user access to a wide range of IoT services.

OCF and oneM2M have developed harmonized standards to permit seamless interworking between oneM2M and OCF environments. This provides a standardized way to create interoperable IoT systems that can address both local and wide-area network scenarios.

[10] www.atis.org

8. Connected home over IP project



Project Connected Home over IP is a new working group within the ZigBee Alliance. This group plans to develop and promote the adoption of a new, royalty-free connectivity standard to increase compatibility among smart home products, with security as a fundamental design tenet. Amazon, Apple, Google, and the ZigBee Alliance joined together to promote the formation of this working group.

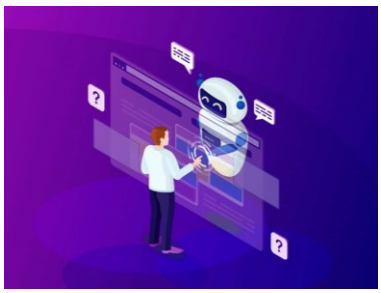
The goal of the Connected Home over IP project is to simplify development for manufacturers and increase compatibility for consumers. The project is built around the idea of secure, reliable, and seamless smart home devices. By building upon Internet Protocol (IP), the project aims to enable communication across smart home devices, mobile apps, and cloud services and to define a specific set of IP-based networking technologies for device certification.

9. Artificial Intelligence

Artificial Intelligence is catching up to automate most actions leaving out the need for user feedback or control. B.One is one of the self-learning home automation and security hub. It runs on the proprietary Artificial Intelligence Engine InstinctAct® which analyzes and predicts actions.

10. ChatBots

In the present scenario users are willing to trade their privacy and personalized experience for hands free easy communication in their natural language, ChatBots offer perfect future solution for the missing components like easy remote access to smart homes with privacy.



ChatBots are emerging as a mode of customized interface, simplifying interfacing and making it more universal.

B.One™ Hub is one of the first home automation hubs to understand and leverage the potential of integrating ChatBots for a highly effective and a wide reaching IoT interface solution.

11. Energy harvesting

Energy Harvesting, ultra-low power devices, long range wireless charging are gaining popularity as Technologies for low power consumption have become important for ensuring longer life for batteries especially in case of wearable device.

Best innovator of CES 2018 won by Wi-change, a wireless product that enable full room wireless-power coverage. Wi-Charge's technology utilizes infrared beams to transfer power between a charging hotspot and client devices within a 10-meter range. Wi-Charge is the first company to achieve the power/range/safety level required for a commercial wireless power solution.

2.4 Technology mapping

Smart home automation solutions involve several constituent elements such as smart home appliances, sensors, relays, hubs or home energy management system, analytics, software to work together. Each of these elements / components has a specific role and together they deliver automation solution that leads to improvement in user comfort and energy savings by efficient operation of appliances and prevention of idle running. In this chapter, an attempt has been made to map major home automation technologies

(including software, hardware and communication protocols) currently available in domestic and international markets. The chapter will also provide technology review to understand hardware and software solutions, challenges with respect to cyber security and the required realignment of individual privacy concepts in India.

The technologies mapped and reviewed in this chapter are broadly classified in hardware and software categories. List of hardware and software elements of smart home automation solutions covered in this chapter are provided in figure below:

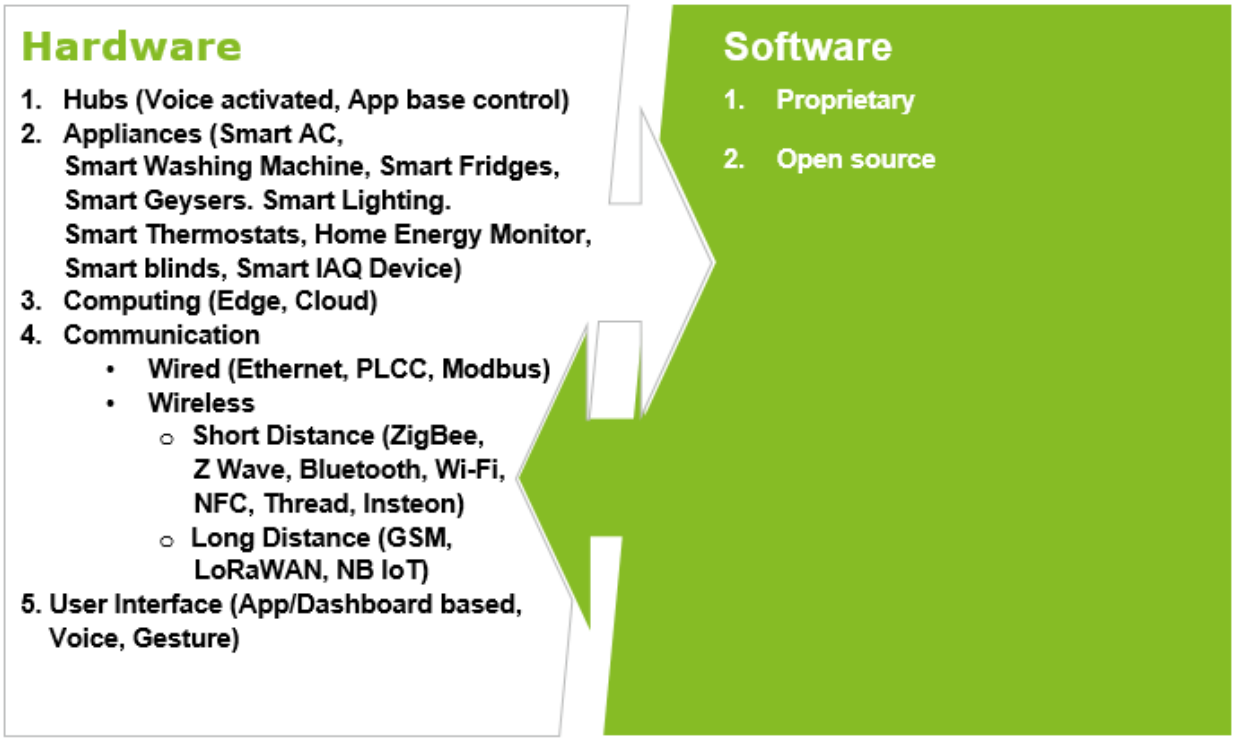


Figure 7 List of hardware and software technology mapped and reviewed

Brief about the hardware and software elements of smart home is provided in subsequent section.

1. Hubs

Two Types of architectures for Smart Homes are possible, hub or without hub. Architecture of smart home without hub can be connected to a common network or/and an independent device such as smart phone. The current trend in smart home automation market prefers a hub that enables interaction between the connected devices. However, in the future, a dedicated hub for smart homes is expected to decline and the hub functionality will be taken over by routers, set-top boxes, smart speakers etc.

Figure 8 Picture of a smart home hub

Concept

A smart home hub is hardware that connects devices on a home automation network and controls communications among them. A smart home hub is a device that collects and translates various protocol communications from smart home devices. It acts as the heart of a smart home network, connecting different devices and systems in a centralized platform. This

also simplifies the network for the user and gives him a unified smart home application to command the various systems and applications.

Hubs may be classified into two categories based on the current technology trends and it includes voice based and app-based hubs.

- **Voice based hubs** have a speaker and user can interact with it over voice commands. Voice based hubs rely on cloud computing and it connects with smart home devices over cloud. Hubs have entered homes through using entertainment as a driver. Value added services are offered by speakers with display for a richer experience giving possibility for home automation console. Major players offering hubs in the market, allow developers to make applications (or skills) and share it with users to create a vast ecosystem.

  Voice based hubs can provide three ways of interacting-voice, touch control and basic mobile app. The biggest concern in the large-scale replication of these systems is privacy as the data collected during daily operation goes to the cloud, which may be hacked.

  These devices generally used Wi-Fi as communication technology which is energy intensive and do not work without internet. Voice controlled hubs can control the smart home system using voice commands by integrating with a smart speaker.

Figure 9 Picture of a voice-based hub

Figure 10 Picture of an app-based hub

- **App based hubs** is a software application which can be operated on any computing device such as mobile, tablet, laptop, PC etc. and it connects smart home devices over either of Wi-Fi, ZigBee, Bluetooth or IR etc.

2. Smart appliances

Smart appliances are the devices that can connect with smart hub or directly with Internet using home Wi-Fi. These devices can push information and receive commands from other devises or the users. Some of these devices can be controlled by utility or the aggregators.

Many manufacturers in India are now offering devices that have some of the smart features, however these features are presently available in premium models only. Based on level of smartness, smart appliances can be broadly classified as:

- **Connected Appliances**: Appliance with an ability to connect to internet and user can operate it from anywhere. Smart features available in these devices include scheduling, multiple operational mode or programs (which may be upgraded through Over the air software update)
- **AI and machine learning based appliances**: In this category, appliance use Artificial Intelligence (AI) and Machine Learning (ML) to adopt to user preferences and external environment to optimize the operating efficiency of the appliance.

Both above category of smart appliances, sometimes include occupancy sensor or geofencing option to prevent idle running when user is not in the vicinity of appliance. Figure providing list of smart home appliance covered in this report is provided in figure below:

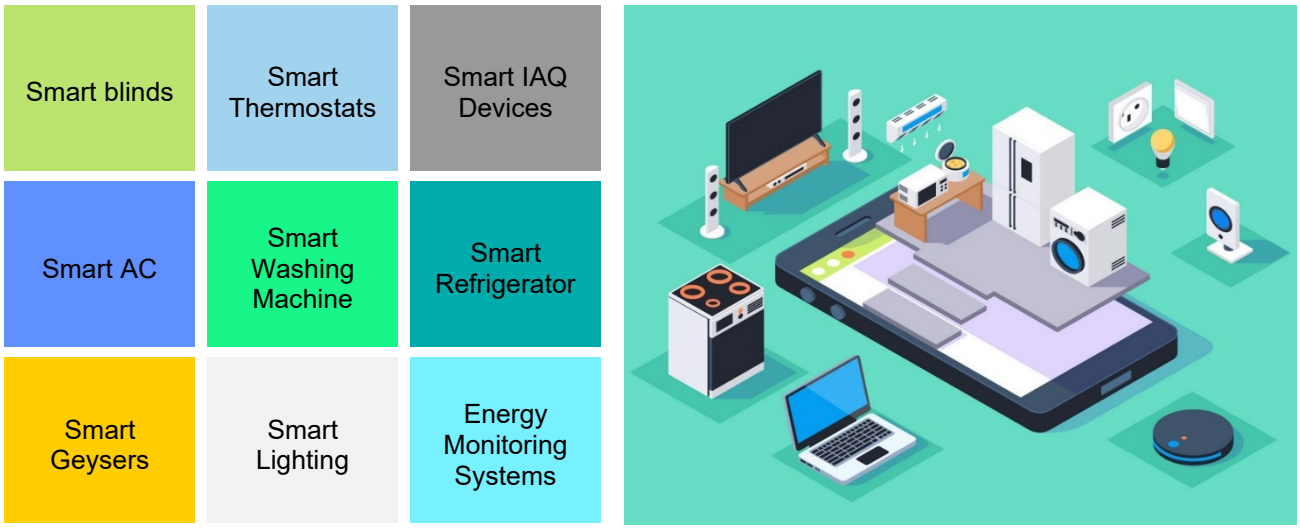


Figure 11 List of Smart appliances

Brief about some of the smart devices which can help in energy savings and demand response is provided in subsequent section.

a) Smart external blinds

Windows form an important aesthetic and interactive element of a building. Windows are used to access outdoor views and natural ventilation. However, it might not always be possible to keep a window open especially when the solar radiation directly falling on the window and adding up to the heat gains inside the space increasing the cooling energy consumption.

For such requirements automatic blinds can be used to control the solar gain by controlling the opening and closing of the blinds. This controls could be executed by using either remote control, scheduling or by deploying sensors to sense solar radiation level, shut the blinds when the threshold level is exceeded thereby saving energy. Motorized window blinds save energy by improving insulation and lighting controls. Features of smart external blinds are provided below.

Table 1 Features of smart external blinds

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Smart hub
Connectivity	Bluetooth, Wi-Fi
Display	Smart phone or tablet
Features	• Voice or app or remote based control • Battery powered, optional solar PV system for charging • Sun tracking and manual scheduling options are available • Can be linked with smart AC, smart hub, smart IAQ devices

b) Smart Thermostats

The smart thermostats can effectively control home comfort whilst learning. The temperature can be adjusted based on time of the day, if it's a weekday or weekend, and more. It provides option of making the home ready when the user arrives at home by providing control access. Programmable option enables maintain a set point on AC that helps user save energy.

Smart thermostats learn from user behaviour and that helps in saving energy. Most smart thermostats have a way of estimating presence of user in controlled home through third-party integrations or geofencing capabilities. Based on the presence of user, the device operates the HVAC system. It learns about the user preferences as the device is being used. Feature of smart home thermostats are provided below.

Table 2 features of smart thermostats

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Smart hub
Connect over	• Wi-Fi
Display	• In build or Smart phone or tablet
Features	• Voice or app-based control • User can monitor, control and schedule (set temperature) thermostat from anywhere • Smart thermostat learns from user preference and keep track of weather conditions to minimize the energy consumption of HVAC system

c) Smart IAQ Devices

Air quality is an evident problem in major cities these days. ISHRAE has defined air quality, noise levels, important parameter to define space quality. Maintaining optimum indoor air quality is energy intensive.

Smart IAQ devices optimize energy consumption whilst maintaining desires air quality. Smart IAQ devices can use sensors to assess the air quality and hence control the functioning of air purifiers by detecting the pollutant levels in the controlled space. Features of smart IAQ products are provided in table below:

Table 3 features of smart IAQ devices

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Smart hub
Connect over	Bluetooth, Wi-Fi
Display	Smart phone or tablet

Particular	Details
Features	• Voice or app-based control • Monitors the Air Quality, temperature and humidity at any time and can be accessed from anywhere • Controls appliances such as air purifier, AC, fan, dehumidifier to Control or maintain air qualify parameters at user preference or set point

d) Smart AC

Smart AC can be controlled using an application that can be operated on any computing device that includes smartphone, tablet, PC, laptop etc. A Smart AC can be remotely controlled from anywhere in the world and its operation can be scheduled.

Modern Smart AC's can also detect infiltration or air leakage from open windows/doors etc. Some of the operating modes of smart AC include:

- Sleep mode
- Eco mode
- Ice bear: ACs with thermal storage.
- Motion sensor for sensing occupancy

Features of smart AC products available in market are provided in table below:

Table 4 Features of smart air conditioners

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Smart Hub • IR remote control
Connect over	Wi-Fi, infrared
Display	Smart phone or tablet
Features	• Voice or app-based control and scheduling • Easily monitors and controls the Air Conditioner at any time and from anywhere • Can control smart blinds and detect air leakage • Have provision of thermal storage to make ice during off peak or low tariff duration and utilize the same during peak or high tariff duration. • 20% - 25% energy savings over conventional AC

e) Smart Washing Machine

Smart washing machines have sensors that detect how dirty the clothes are and allows the user to control the washing duration using an application that can be operated on any computing device that includes smartphone, tablet, PC, laptop etc.

Users can also download new washing programs and it can be configured in smart washing machine for sequent

use. Features of smart washing machine are provided in table below:

Table 5 Features of smart washing machine

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Smart Hub • Dashboard on machine
Connect over	Wi-Fi, infrared
Display	Smart phone or tablet
Features	• Smart Sensors for low voltage usage and smart detergent dosage. • Multiple wash and dry options/program based on cloth type and how dirty clothes are. • Can be operated from anywhere • Smart selection of wash/dry program reduces wash time and energy consumption. • Wash program can be updated over the air same as any mobile apps

f) Smart Refrigerator

Smart refrigerators feature a touchscreen interface and ability to connect to the internet through Wi-Fi. Smart refrigerators include internal cameras, more flexible user-controlled cooling options, and the ability to interact with its features using a smartphone or tablet.

Some smart refrigerators can even connect with other smart devices in the home; such as speakers, smart TVs, and even smart dishwasher or smart microwave. Features of some smart refrigerators available in market are provided in table below:

Table 6 Features of smart refrigerators

Particular	Details
User interface	Touch: Manufacturer app Voice: In built smart speaker or through smart hub
Connect over	Wi-Fi
Display	In Build Display or smart phone or tablet
Features	• User can see inside refrigerator without opening door using cameras to prevent frequent opening • Run specific programs such as vacation mode etc. • Can alter set point of freezer and other zones of refrigerator based on external weather conditions, quantity and type of stuff kept inside. • Can provide recipe ideas for health improvement and order groceries • Look up the weather • Bluetooth speakers also let user stream music • Can control other smart appliances such as geysers, AC etc.

g) Smart Geysers

Smart Geysers is an IoT-enabled, high efficiency, smartphone-compatible water heater with cloud-based functionality. A smart water heater can be switched on/off, scheduled, monitored, and operated from anywhere in the world, using application that can be operated on any of the computing devices that includes smartphone, tablet, PC, laptop etc.

Smart geysers set the timer to keep the geyser on up to the temperature based on user preference, instead of heating the straight to the maximum limit. This reduces the temperature gradient between the geyser water and the environment and heat loss occurs at a slower rate. Also, the timing of operation of smart geyser is estimated using AI based learning of consumer behaviour, peak events of grid and electricity tariff. Feature of smart geysers are provided in table below:

Table 7 Features of smart geyser

Particular	Details
User interface	Touch: Manufacturer app Voice: Smart hub
Connect over	Wi-Fi
Display	In Build Display or smart phone or tablet
Features	• User can set temperature and schedule the geyser using app or touch panel • User can monitor and control geyser from any where • Can monitor user preference of temperature and keeps water ready at preferred temperature and preferred time

h) Smart Lighting

Smart lights can incorporate a variety of sensors, including motion sensors. This enables them to turn on only when presence of user is detected in controlled area. When user is not present, light may turn off or luminous intensity may be reduced based on user preference. These features of smart light save substantial amounts of energy by avoiding idle running of lighting system.

Using smart sensors that may detect the amount of sun light can help in adjusting the luminous intensity to meet the user needs. This feature of smart light may also be used to increase luminous intensity on mornings with heavy fog. Features of smart lighting are provided in table below:

Table 8 Features of smart lighting

Particular	Details
User interface	Touch: Manufacturer app Voice: Smart speaker or smart hub
Connectivity	Wi-Fi, Bluetooth, ZigBee
Display	Smart phone or tablet
Features	• Option of multi-level dimming is available. • User can monitor and control light from anywhere using smart phone • User can change light colour based on requirement

i) Energy Monitoring Systems

Energy monitoring systems (EMS) are used to monitor the real time power consumption. Using the smartphone app, live alerts regarding usage of each appliance can be obtained. EMS allows to track energy consumption of appliances and track monthly energy statistics.

Based on the feedback and analysis of the present and past energy consumption trends insights for energy saving may be identified. Home energy Monitoring systems are mainly divided into 3 categories:

1. Non-Intrusive Load Monitoring (NILM)

With NILM user can estimate real time power consumption of active appliances using main meter aggregated power or current data. The application or dashboard will give the real time power consumption of the identified appliances and aggregated power consumption.

Features:

- Real time monitoring of aggregated power and individual device power consumptions in seconds.
- Automatically identify the heavy load appliances and gather real time power consumption of appliances. By taking feedback or by using various algorithms.
- Smartphone application and dashboard shows how and when appliances are used and how much energy they consume.
- Monitor the solar production, in case rooftop solar installed.
- Feedback based on real time pricing is also given.
- User can analyze energy trend and receive monthly reports.

2. Intrusive Load Monitoring - Circuit level monitoring

In this energy monitoring system, a smart meter is installed at the circle level to monitor and control the heavy appliances. It monitors the connected device.

Features:

- Real time monitoring of the power consumption of the single heavy load appliance.
- Smartphone application or dashboard is used to give the feedback.
- Appliances can be controlled using a mobile phone.
- Connectivity: Wi-Fi
- Scheduling of the connected devices.
- User can analyze energy trend and receive monthly report.

3. Intrusive Load Monitoring - Plug load monitoring

The plug load monitoring device monitors energy consumption of appliances when they are plugged in. Smart sockets or plugs fall under this category.

Features:

- Real time monitoring of the power consumption of the plug load.
- Smartphone application-based controls.
- User can control from anywhere via mobile application.
- Voice controls using smart speakers.
- Prevent power-hungry devices from being left on longer than needed and based on user's geo-location.
- User can schedule or set action for the smart socket to automatically on and off appliances.
- User can view energy consumption and cost in real time.

3. Computing

Computing of the data gathered by sensors in smart home automation system is processed for analytics and it is also stored to develop artificial intelligence regarding user behaviour and preference. In smart home automation systems, the computation may classified in two categories based on type of computation, this includes cloud computing and edge computing.

a) Cloud Computing

The Cloud-based-Networking system involves storage and maintenance of data over the Internet location. This gives users the flexibility to have access to the data from any location on the planet.

In IoT based Home Automation systems, users can send commands to the hub even from a distant or remote location over the cloud network. The hub will further send the signal for the intended sensors to trigger and perform the user-requested action. Once the action is performed, the hub will update the status of the action taken to the cloud network and in this way, users can control and monitor every aspect of their smart homes.

The cloud services include smart home device tracking, configuration, analysis, reporting, authentication and authorization services. These functions provide value added service for users to control and manage their smart homes using different means (e.g., web and mobile applications) as well as to interact with third party vendors.

Since the data processing and storage is done on remote server there are certain challenges associated with cloud computing for smart home automation systems. Major challenges of cloud computing are mentioned below:

- Sending the huge data generated from connected devices to remote server causes latency issues and delays in the transfer of data. This is a major issue specifically in real time analytics and time critical actions
- High security risk of the data in flight from smart home to remote server and the data stored on the remote server
- Privacy concern with complete information of smart home going outside & getting stored in distant server.
- No functionality of the system in the event of Internet outage
- Possibility of system rendered useless when the service provider stops support or closes the business.

b) Edge Computing

With the advent of edge analytics and fog computing, the above challenges are addressed, bringing intelligence, performance, security and privacy in smart homes:

- Edge Intelligence is based on the concept to bring data processing from the cloud to the field, i.e. to the smart home where sensors, devices are deployed.
- Depending on the processing requirement, the data collected from device is either processed at the device itself known as edge analytics or at the local node deployed at the periphery of home network known as fog computing.
- The analysis and decision taken at edge or fog node is fed to the device for the next action in real time.
- Only a subset of data is transmitted to remote server. Sensitive information can be processed at Edge allowing only non-sensitive information to be sent to server. This helps in real time data processing without latency, reduces privacy/security risks and optimizes the network resources.

Schematics of edge computing architecture is provided in figure below:

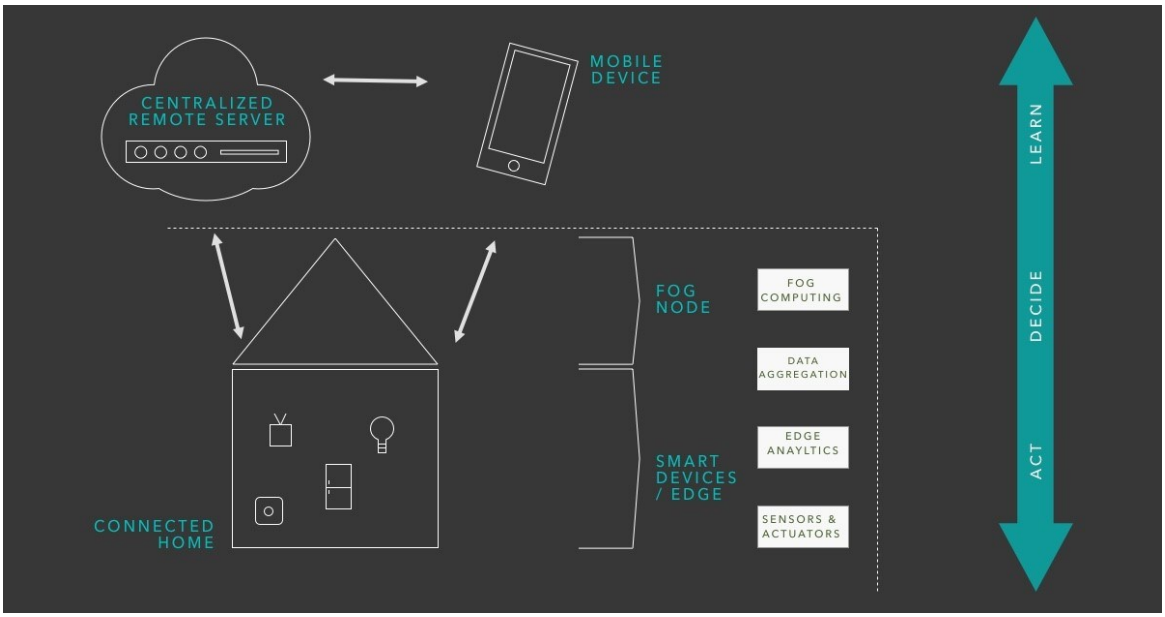


Figure 12 Schematics of Edge computing architecture

Edge computing is a part of a distributed computing topology in which information processing is located close to the edge – where things and people produce or consume that information.

4. Communication

Communication protocols used for smart home automation solutions can be classified in two categories based on physical connection of smart home devices, this includes wired and wireless communication protocols. The wireless communication protocol can be further classified in two subcategories based on range of communication, this includes short and long distance. Figure showing categories of communication used in smart home is provided below.

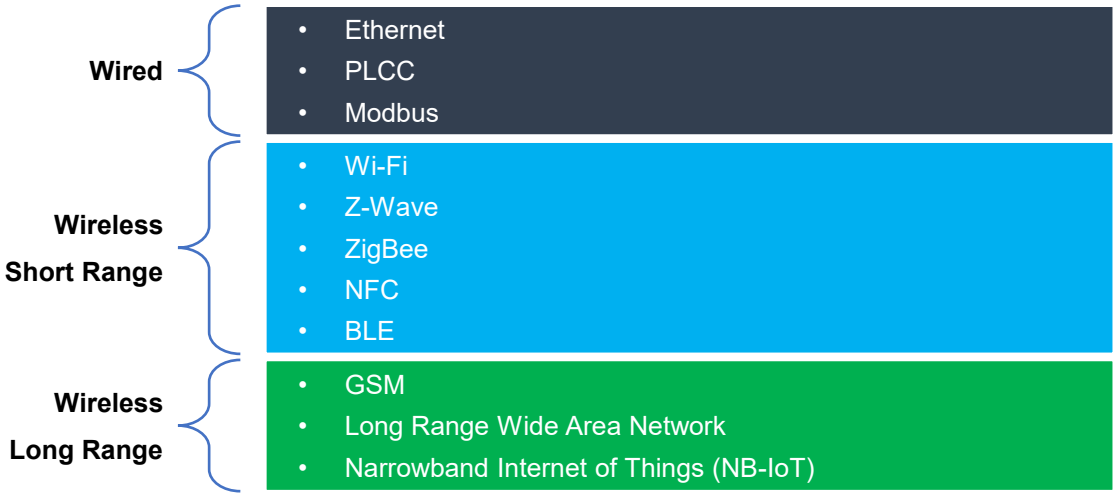


Figure 13 Type of communication protocols in smart homes

Details of each category of communication protocol is provided below:

a) Wired

➢ Ethernet

Ethernet is a wired communications standard that allows large quantities of data to be sent at high speed. It is the leading communications method for internet traffic. The Ethernet standard is maintained by the Institute of Electrical and Electronics Engineers (IEEE).

➢ Power Line carrier Communication

PLCC has been used in the past for metering at remote locations. The present-day applications of PLCC is in home automation, high speed internet access, smart grid etc.

➢ Modbus

Modbus is a communication protocol developed by Modicon systems. It is a method used for transmitting information over serial lines between electronic devices. Modbus is an open protocol, i.e. it's free for manufacturers to build into their equipment without having to pay royalties. Modbus is typically used to transmit signals from instrumentation and control devices back to a main controller or data gathering system.

b) Wireless

➢ Short Distance

- **Zigbee:** It is one of the advanced protocols used for home automation technology. It is connected through the radio frequency with complete wireless technology. It can operate multiple devices at a time and is an open technology which gives comfort to the designers to design compatible products. It consumes less power and eliminates the usage of battery. It is a secured home automation protocol that is highly customizable.
- **Z Wave:** Z-Wave is a procedure which is connected using the radiofrequency. It is easy to set up and is an energy-saving solution with the Z-wave frequency used for the wireless devices. It makes communication faster and compatible with several brands. More than 1500 certified compatible devices for the Z-wave is available. It has a frequency of 908.42 MHZ that lets user connect the home device easily.
- **Bluetooth:** Bluetooth technology is commonly used in light bulbs and smart door locks. The best part of using the Bluetooth is that it can be coupled with multiple other products which have the same connectivity feature. Bluetooth provides a range of about 10 meters at the speed of 1Mbps and it also consumes very less power.
- **Wi-Fi:** Wi-Fi is one of the most convenient protocols to work with for home automation devices. Wi-Fi protocols provide a ready-made infrastructure with an inherent ability to manage high quantities of data. Another advantage of using Wi-Fi protocol for home and office automation is the in-built AES 256-bit encryption. Appliances can be controlled using a personal computer through Wi-Fi. Most Wi-Fi devices uses the 2.4GHz frequency and implement frequency division multiplexing technology. One major drawback with Wi-Fi technology is that it consumes a lot of power, hence leads to very fast battery drainage.
- **NFC:** NFC technology is designed for an operation distance of a few centimeters, which makes it difficult for attackers to record the communication between an NFC Forum Device and an NFC Forum Tag as compared to other wireless technologies that have a working distance of several meters. Additionally, the user of the NFC Forum Device determines by the touch gesture, which entity the NFC communication should take place, this makes it very tough for the attacker to get connected. Hence, the security level of the NFC communication

is higher compared to other wireless communication protocols. Additionally, the NFC Forum has added Peer to Peer communication which is a mechanism to cipher all exchanged data to avoid the interpretation of recorded communication.

Table 9 Features of major short distance communication protocols

Particular	Wi-Fi	Z-Wave	ZigBee	NFC	BLE
Power Efficient	No	Yes	Yes	Yes	Yes
Data Bandwidth	High	Low	Low	Low	High
Frequency Band	2.4GHz	900MHz	2.4GHz	13.56 MHz	2.4GHz
Topology	Star	Mesh	Mesh	Only supports direct communication.	Scatternet
Alliance	Wi-Fi Alliance	Z-Wave Alliance	ZigBee Alliance	NFC Forum	Bluetooth SIG

➢ Long Distance

- **GSM:** Any IoT application that requires operation over longer distances can take advantage of GSM/3G/4G cellular communication capabilities. While cellular can send high quantities of data, especially for 4G, the expense and also power consumption will be too high for many applications. It can be ideal for sensor-based low-bandwidth-data projects that will send very low amounts of data over the Internet.

    - Standard: GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G)
    - Frequencies: 900/1800/1900/2100MHz
    - Range: 35km max for GSM; 200km max for HSPA
    - Data Rates (typical download): 35-170kps (GPRS), 120-384kbps (EDGE), 384Kbps-2Mbps (UMTS), 600kbps-10Mbps (HSPA), 3-10Mbps (LTE)

- **LoRaWAN**: Long Range Wide Area Network is a protocol for wide area networks. It is designed to support huge networks (e.g. smart cities) with millions of low-power devices. LoRaWAN can provide low-cost mobile and secure bidirectional communication in various industries.
    - Standard: LoRaWAN
    - Frequency: Various
    - Range: 2-5km (urban area), 15km (suburban area)
    - Data Rates: 0.3-50 kbps

- **NB IoT:** Narrowband Internet of Things (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio technology standard developed by 3GPP to enable a wide range of cellular devices and services. NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency, especially in deep coverage. Battery life of more than 10 years can be supported for a wide range of use cases.

5. User Interface

User interface in the smart home devices can majorly classified into 3 categories:

- **App/dashboard based**: App/dashboard UI allows user to control, monitor and manage all the smart devices present in the home by using a tablet or smartphone. User can monitor past readings. User can schedule the various devices or write rules for different appliances. Controls can be performed remotely using mobile application. Examples of app/based user interface include apple home, google home, Samsung thing app, smart things etc.
- **Voice based:** Voice UI allows user to control the devices by giving voice command. It is mostly used in the private places like homes, private cars and enclosed office. It enables the hands-free computing. For example, a user can adjust light, control temperature, or many other devices by giving commands without moving to manual control panels. Voice UI is based on NLP implementation and IOT. Example of voice-based user interface includes ALEXA and google assistant based home automation devices.
- **Gesture based:** Gesture UI allows user to control the devices by providing gesture. It provides remote less environment to the users. Gesture UI is generally based on computer vision (CV). For instance, a user can adjust the lighting level or thermostat level by moving the hands. Examples of gesture-based UI include Ubiquilux, Nest thermostat (singlecue Gen 2), Piccolo, Otodo etc.

6. Software

a. Proprietary

Proprietary software, also known as closed-source software, is a non-free computer software for which the software's publisher or another person retains intellectual property rights (usually copyright of the source code, but sometimes patent rights). List of some of proprietary software and associated smart home technologies are provided in table below:

Table 10 List of proprietary software for smart home automation

Name	Technologies
AMX LLC	Configuration tools only work on Windows.
Control4	Uses a Linux kernel, configuration tools only work on Windows. Platform also supports open hardware utilizing the Z-Wave standard.
INSTEON	Lighting, appliances, sensors. Mobile apps for Android and iOS, configuration tools only work with Windows.
Lutron	Focused on lighting and shades, configuration tools only work on Windows.
SmartThings	Lighting, appliances, sensors. Mobile apps for Android and iOS.
Vivint	Sensors and one-touch hardware for security.
B.One	Energy Management and Lighting control

b. Opensource

Open-source software are computer software in which source code is released under a license in which the copyright holder grants users the right to study, change, and distribute the software to anyone and for any purpose. Open-source software may be developed in a collaborative public manner. List of some open source home automation software is provided in table below.

Table 11 List of open source software for smart home automation

Name	Properties
Node-RED	Node-RED is a programming tool for wiring together hardware devices, APIs and online services in new and interesting ways. It provides a browser-based editor that makes it easy to wire together flows using the wide range of nodes in the palette that can be deployed to its runtime in a single-click.
Domoticz	Domoticz is a Home Automation System that allows to monitor and configure different devices like Lights, Switches, various sensors and meters like Temperature, Rain, Wind, UV, Electra, Gas, Water and many more. It also lets to send notifications/ alerts can be sent to any mobile device
OpenHab	The **open H**ome **A**utomation **B**us is an open source, technology agnostic home automation platform which runs as the center of smart home!
HomeAssitant	Open source home automation that puts local control and privacy first. Powered by a worldwide community of tinkerers and DIY enthusiasts. Perfect to run on a Raspberry Pi or a local server

2.5 Techno commercial analysis of high impact technologies

The devices included in this section are broadly classified into smart home devices (and appliances) and smart home retrofits. In most of the techno commercial analysis, the baseline is assumed based on the guidelines of BEE S & L scheme, using building energy simulation tools and energy saving potential is estimated based on various pilot studies, research publications, and manufacturer claim.

Some of the mentioned energy saving reference may not be directly applicable for Indian context (climate conditions, user behaviour and lifestyle, construction type, cost of energy). Hence, there is a need to conduct field studies and pilot trails, in multiple climatic zones and variable situations to compare conventional appliance used in home with smart home appliances (and devices). Summary of findings of techno commercial analysis of major smart home devices and retrofits (based on publicly available information) are presented below:

Table 12 Energy saving potential of smart home devices

S. No	Description of smart measures	Percentage Energy savings (%)	Simple payback period (Year)
Smart appliances or devices			
1	Smart Geyser	9% - 16%	1.6 – 3.4
2	Smart AC	17%	3.8
3	Smart Washing Machine	19%	3.9
4	Smart Lighting	40%	3
5	Smart External Blinds	29% - 38%	4.7 – 7.2
Smart Retrofits			
6	Smart plug enabled geyser	1% - 8.5%	0.25 – 0.6
7	Smart plug enabled washing machine	20%	0.8
8	Occupancy sensor for light and exhaust fan control	46%	2.7
9	Energy Monitoring System	4 – 12%	3
10	IR blaster enabled AC	9%	1.2

Details about techno commercial analysis for above mentioned smart appliances and smart retrofits is provided in annexure 1.

2.6 Factors affecting smart home device performance

Smart homes automation technologies may lead to significant energy savings and / or usage pattern optimization and contributes to wider energy system benefits by preventing idle running, reducing standby losses and optimization of operating parameters of energy consuming systems while maintaining the user comfort and convenience. Net energy savings from smart home automation technologies depends upon range of factors, same are provided in figure below:

Type of intervention

- **Manual intervention**: Real time energy consumption data collected by sensors or smart appliances is provided to user and user controls the energy consuming devices based on received data or energy saving tips
- **Automatic intervention**: In such advanced home automation system, the hub or home energy management system monitors and controls energy consuming appliances to maintain preset value or parameters deduced from user preference and ambient conditions

Level of controlling available

- Controlling options available such as turning on or off devices or fine tuning of operating parameters to make the device work more, or less efficiently.

Design and operating efficiency of energy consuming system

- Quantum of energy saving will depend upon how much energy efficient system is installed in the house and how well it is maintained and operated.

User preference

- Whether energy efficiency is a priority and there are robust algorithms to ensure energy efficiency in different situations or whether automation is based on user preferences with no or marginal consideration of energy efficiency.

Figure 14 Factors affecting energy savings of a smart home automation system

3. Baseline assessment of Indian Smart Home Market

3.1 Background

Home automation systems or smart home concept has witnessed an unprecedented growth in the recent years in India due to factors which mainly include increased concerns about safety & security (especially in urban areas) and penetration of product and services that enhances consumer experience by adding comfort and convenience. Moreover, factors such as increase in disposable income, penetration of smartphones, availability of internet connectivity at affordable rates and surge in awareness about smart systems have also boosted the adoption, thus driving the India home automation market growth.

For baseline assessment regarding smart home automation market in India, project team undertook primary research to understand the market characteristics, dynamics, consumer preference and potential future scenarios. Primary research methods employed for this study included online surveys and interviews. Overall methodology of the study is divided in three broad tasks which included:

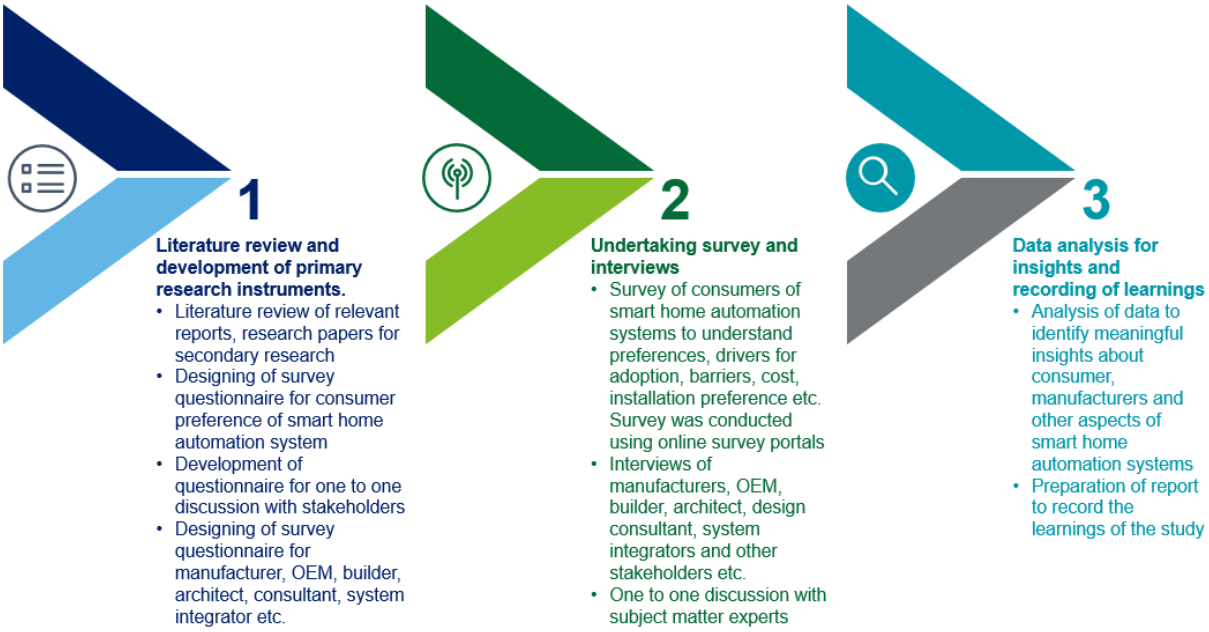


Figure 15 Methodology of baseline assessment

3.2 Findings of baseline assessment

- The market for Smart Homes in India is estimated at US$ 355.4[11] Million in 2016 and it was expected to grow at 43.75% (CAGR) from 2016 to 2020. Based on the provided growth rate, the present market size for smart homes is estimated at US$ 1 Billion.
- Total number of households in India were 187[12] million in 2001 which has increased to 244.7[13] million by 2011. The number of households in India are growing at a CAGR of 2.7% per year. Based on the data regarding average spending on smart home automation products and services, collected during

[11] Technical report on Smart Homes (March, 2017) by Telecommunication Engineering Centre, Ministry of communication, GoI
[12] Data as per census report 2001
[13] Data as per census report 2011

the consumer survey, the penetration of smart home automation products is estimated as 0.07% in 2016 and it is expected to increase up to 0.20% by end 2020.

- At present, most preferred smart home products/service for Indian consumers[14] are related to home security. It is followed by the applications such as smart lighting and smart infotainment systems that primarily enhances comfort and convenience. Majority of the consumers are not opting for smart home automation systems primarily for energy saving. However, as most of the automation systems prevent idle running of energy consuming appliances and matches the operating parameters according to consumer needs, some extent of energy savings is being accrued to the consumer as a byproduct of the smart home automation products.
- In current scenario most opted point of sale or distribution channel is through system integrator as level of awareness for selecting product type and configuration is still low for most of the consumers. In this scenario, system integrator provides end to end solution of selection, installation, configuration and maintenance.
- With regards to impact of building codes and green rating, about 55% of surveyed manufacturers/service providers indicated that there is no impact of mentioned policies on demand of their product and services. 36% of the respondents have no opinion in this context and about 9% of the respondents agree that the mentioned policy have an impact on demand of their product and services.
- Home automation has been viewed as a luxury element in homes in India until recent years and use of such products was limited to elite population. However, with penetration of smartphones, availability of high-speed internet connectivity at affordable rates and increase in disposable incomes, middle class population has also entered home automation market and now have a significant impact on market size and solutions being offered in this space. Along with positives mentioned above, there are some challenges in penetration of smart home automation systems which include non-availability of good quality and reliable power supply, lack of inter-operability of available products, limited options of system integrators etc. During the survey and interviews with relevant stakeholders several drivers, barriers and opportunities were identified, details about the same is provided in figure below:

[14] Based on consumer and manufacturer/service provider survey undertaken as part of this assignment

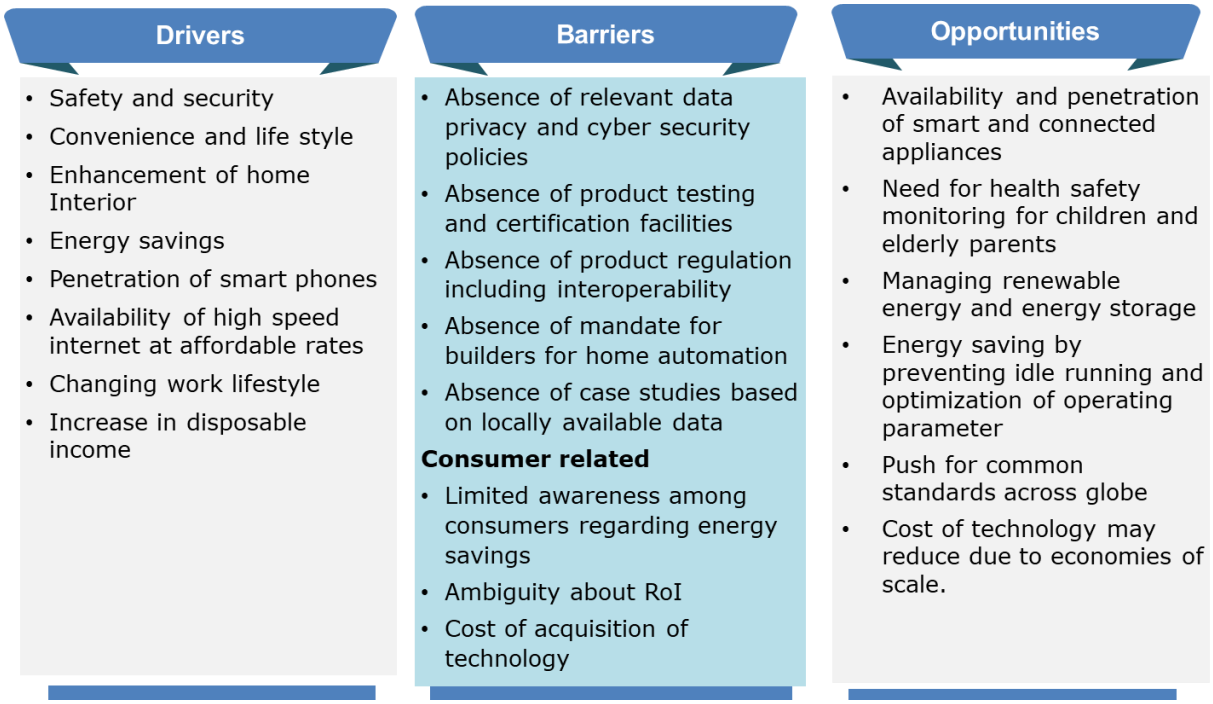


Figure 16 List of drivers, barriers and opportunities

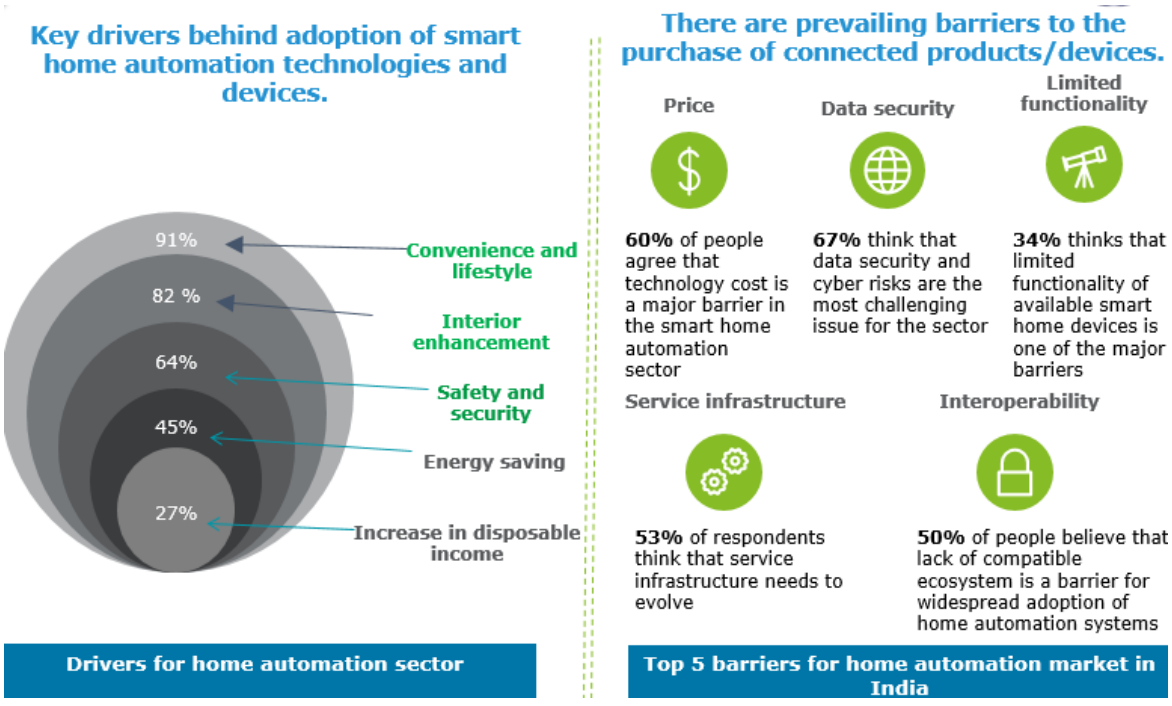


Figure 17 Quantitative analysis of drivers and barriers

- To understand the consumer needs, preference, awareness and barriers regarding smart home automation technologies/solutions, a consumer survey was conducted. Following table provides the summary of findings of consumer survey and subsequent sections provides results and inference of consumers gathered during survey on various aspects of smart home automation systems.

Particular	Details	Survey outcome
Product preference	First preference	Security and access control devices
	Second preference	Smart lighting
	Third preference	Smart Audio Visual (AV) system
	Overall	Most preferred smart home automation systems are security and access control devices. It is followed by the applications such as smart lighting and smart AV that primarily provides comfort and convenience. Smart home application that provides energy saving opportunities are currently 4th and 5th choice of the consumer.
Cost of smart home automation system	For house upto cost INR 80 Lakhs	3.2% of house cost
	For house costing INR 80 Lakh to 2 Crore	4.4 % of house cost
	For house costing INR 2 to 5 Crore	4.8% of the house cost
Key drivers for adoption	Major drivers	Convenience and lifestyle, enhancement of home interiors and safety and security
	Other drivers	Energy saving
Major barriers	Major	Data security and cyber risk, high cost of the technology, lack of compatible ecosystem or standardized products and lack of reliable after sales services
	Other	Limited functionality of current offerings (i.e. lack of single ecosystem), complexity of installation and lack of clarity on expected energy savings that governs return on investment
Installation preference	Major	OEM or service provider
	Other	Builder, Do it yourself (DIY)
View on need of single ecosystem	Major	• 68% of the users would like to have a single ecosystem
	Other	• About 16% consumers are comfortable with products working on multiple communication or operating systems • About 17% of the respondents do not have a view in this matter

Particular	Details	Survey outcome
Diversity of respondents	City of dwelling	Mumbai, Delhi NCR, Bengaluru, Pune, Chennai, Hyderabad, Coimbatore, Kolkata, Thane, Sirsa, Jaipur, Dehradun, Cuttack
	Age groups	• Less than 30 Years • 30 to 40 Years • 40 to 50 Years • 50 to 60 Years
	Annual household income	• Less than INR10 lakhs • INR 10 to 20 lakhs • INR 20 to 30 lakhs • INR 30 to 50 lakhs • More than INR 50 lakhs
	House size	• 1BHK • 2BHK • 3BHK • 4BHK • Independent Bungalow
	Ownership status	Rented or Owned

3.3 Barriers and policy requirements indicated by stakeholders

Based on survey and interviews of stakeholders, major barriers to penetration of smart home automation products and services were identified. List of barriers, where stakeholders suggested requirement of policy interventions include:

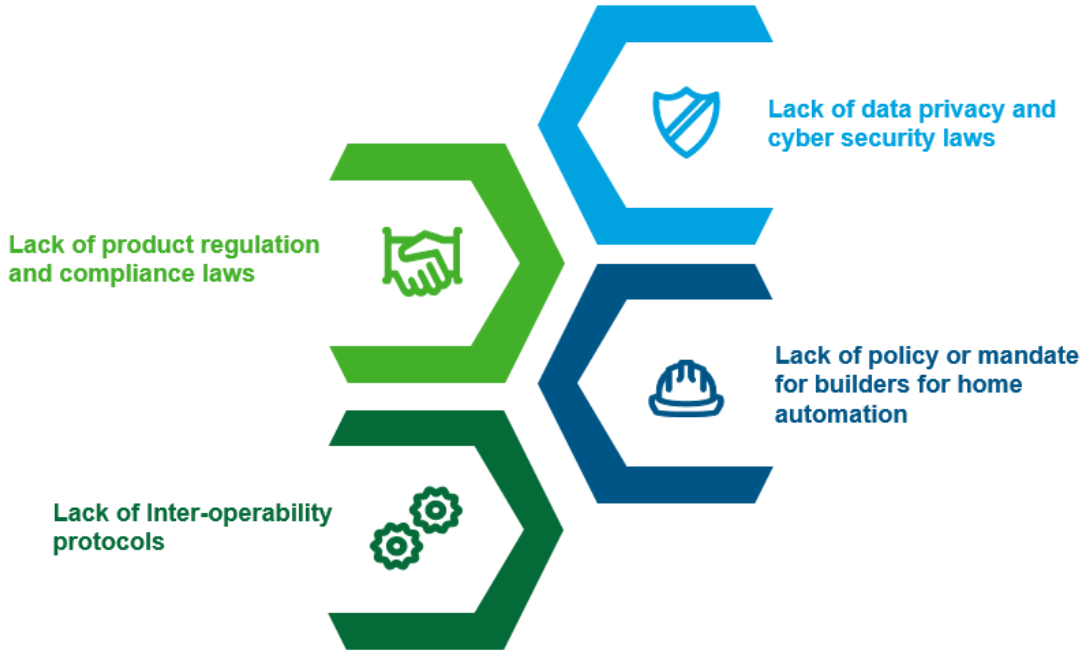


Figure 18 Major barriers to adoption of smart home identified in stakeholder consultation

- **Product regulation and compliance laws**

  Absence of product regulation or compliance law is a barrier for growth of smart home automation systems. At present, OEMs and developers do not have standard guidelines (including minimum energy efficiency), electrical and electronic safety standards for developing new applications and hardware for Indian market. The certifications and standard available at international level regarding hardware, software and communication (in terms of frequency) may not match local requirements.

- **Data privacy and security threat**

  India is yet to implement data privacy laws and regulations. This is one of the principal concerns to OEMs and service providers as big data has to be collated at a central server to analyse and build AI trends. Home automation command via voice and gestures will be widely accepted as part of the 'Human- Home Automation Interface' (HHAI) and is believed to be the turn-around for the entire home automation market acceptance. HHAI happens through a wider collation of big data and thereupon works on the application of Natural language processing and Image processing which needs big data processing. The Data Privacy law may prevent misuse of data gathered over global servers for such processing.

- **Lack of Inter-operability protocols**

  Majority of the consumers are concerned about lack of interoperability of products currently available in market. Under this scenario, consumer choices, after installing product from a certain supplier, becomes limited, as most of the brands/suppliers have proprietary standards and protocols, which makes installation of device from any other supplier nearly impossible. The standards of inter-operability or standardization of products and communication systems, can resolve this concern.

- **Lack of policy or mandate for builders for home automation**

  In India, majority of the homes are constructed by realty developers. In absence of a policy guideline or mandate, this mass housing segment does not target home automation as a pre-sales option. The later (post occupancy) adoption of home automation by a consumer becomes difficult and costly affair, as the enabling fittings/provisions needs to create afresh, and cost of product/services increase as option of demand aggregation for economies of scale is not available. Based on consumer survey, list of smart home solutions, which should be mandated as standard installation were identified and responses are provided in figure below:

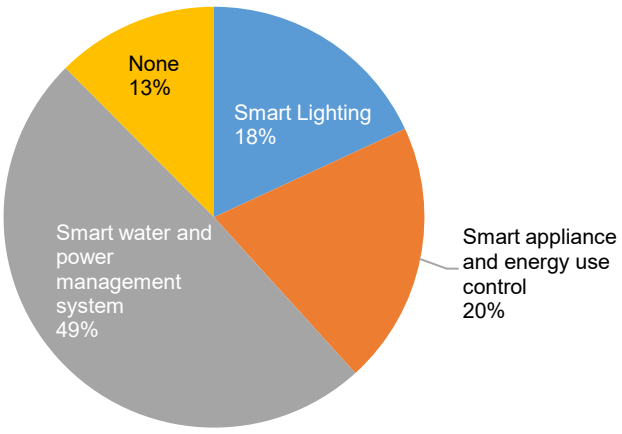


Figure 19 List of smart home solution consumer prefer as standard installation in new home

Based on the consumer responses, it can inferred that about 49% of the respondents would like to have home automation system which help in water conservation and power back up as standard installation in new home, followed by smart appliances and energy use control (20%) and smart lighting (18%). About 13% of the respondents believe that home automation solutions should not be included in standard installations.

3.4 Market Growth and forecast

Globally smart home products and services are penetrating homes through devices like routers, set-top boxes, voice-controlled speakers and in the form of smart appliances. Using communication, convenience and entertainment as the value proposition, industry players are introducing the concept of smart devices to householders and are creating a niche platform to establish a dedicated market for their products and related services.

Indian smart home market is presently in its nascent stage, as confirmed by industry representatives and subject matter expert during survey and interviews. Due to this fact, there is a limited availability of historical data regarding total market value, past growth trends and future growth expectation. Demand / market forecast has thus been carried out by adopting following approach:

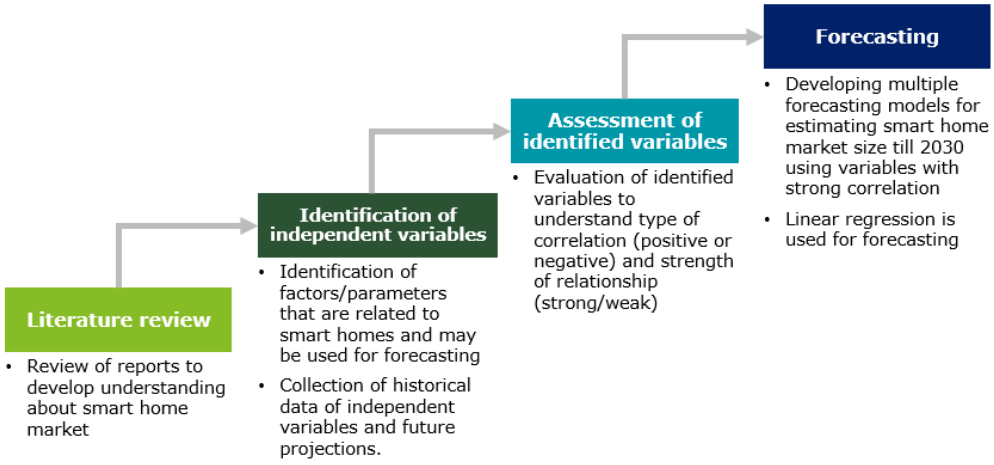


Figure 20 Methodology for market growth forecasting

Results of market growth forecast

Based on the forecasting models developed as part of this report, the Indian smart home market size is expected to be in range of US$ 6 to US$ 20 billion by the end of 2030 without any major policy intervention.

Some of the key policies required to disrupt Indian smart home market identified based on the discussion with industry leaders and subject matter experts, include:

- Policy for data safety and cyber security to protect consumer privacy and to mitigate risk of data theft.
- Policy to standardize products for seamless integration of products of different make
- Policy to promote use of smart home in new and existing homes by voluntary or mandatory compliance.
- Scheme to promote development and implementation of demand response program

The figure indicating estimated growth of Indian smart home market size with and without policy intervention is provided in figure below:

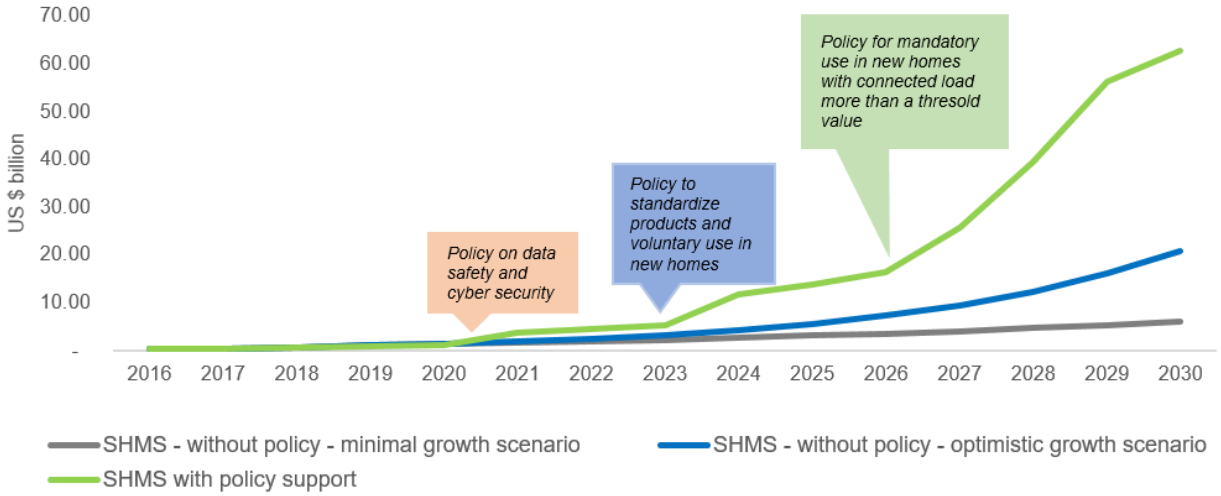


Figure 21 Forecast for smart home market size, with and without policy intervention

Smart home market size – without policy intervention

In absence of any major policy interventions, the smart home market is expected to reach US$ 20 billion in optimistic growth scenario and US$ 6 billion in minimal growth scenario.

Smart home market – with policy intervention

Indian market may follow the trends like other developed nations, where the smart home market is expected to grow by 10 folds[15] with implementation of some of the much-needed policies (listed above). Considering this factor and reduction in cost of technology with economies of scale, Indian smart home market size is expected to grow to about US$ 62.8 billion by the end of 2030 (with regular policy interventions by concerned departments) and the penetration level (with reference to total number of households in 2030) is exacted to reach 28%.

Considering the above-mentioned penetration at national level, energy saving potential by adoption of smart home devices is expected to be 94 billion units in 2030, which will be about 15% of electricity consumption of residential sector in 2030.

On human resource and skill development front, smart home market is expected to add about 2.5 to 3 million new jobs by 2030. These jobs will be created with manufacturers, OEMs, data and service providers, system integrators, architects, consultants and with other related stakeholders.

[15] As per Intelligent Efficiency – Case study of barriers and solutions – smart homes report (Connected device alliance report, the smart home device penetration in US was 5% in 2015. As per Statista estimate the US smart home device penetration in expected to reach about 51.4% by 2024. As of now US have policies on data privacy, IoT device standardization and Energy star labeling for smart home energy management system (SHEMS)

4. Global policy review

4.1 Background

For review of global policies and plans related to smart home technologies and demand response, secondary research was carried out and information was collected about smart home standards, certification, interoperability, demand response program etc. In addition to this, several national and international experts were consulted to understand the global policy landscape. The methodology of the study is thus divided in following broad tasks:

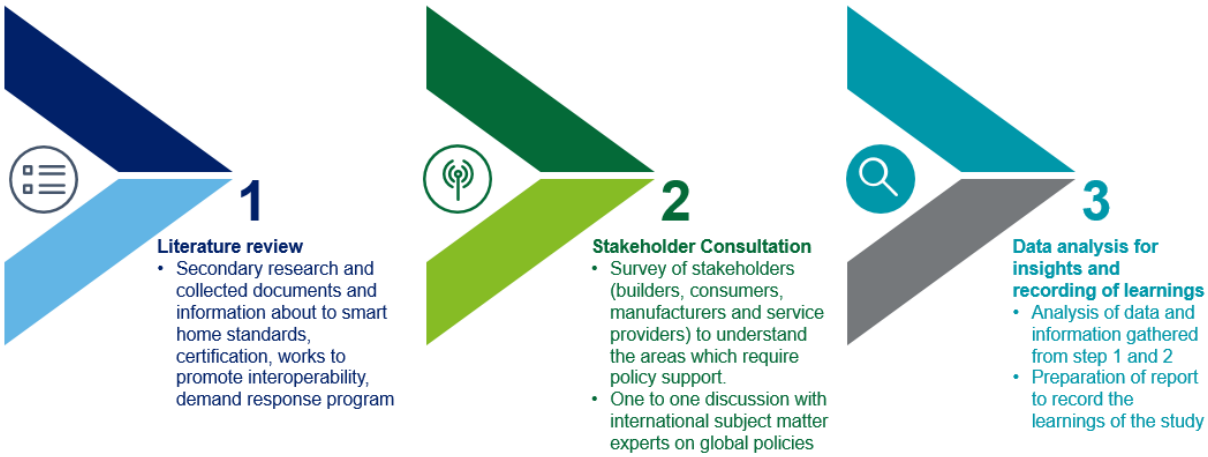


Figure 22 Methodology for review of global policy on smart home and demand response

4.2 Review of global policies on smart home and demand response

To promote use of home automation systems (for energy efficiency improvement and for demand response) and to overcome barriers to adoption of smart home technologies (such as lack of interoperability, lack of data privacy and cyber security, high cost of technology, ambiguity about energy and cost savings etc.) several countries and geographies have developed various plans, policies, standards and certification systems for these home technologies. Based on review of available information in public domain, research publications, the global policy landscape can be broadly classified in four categories.

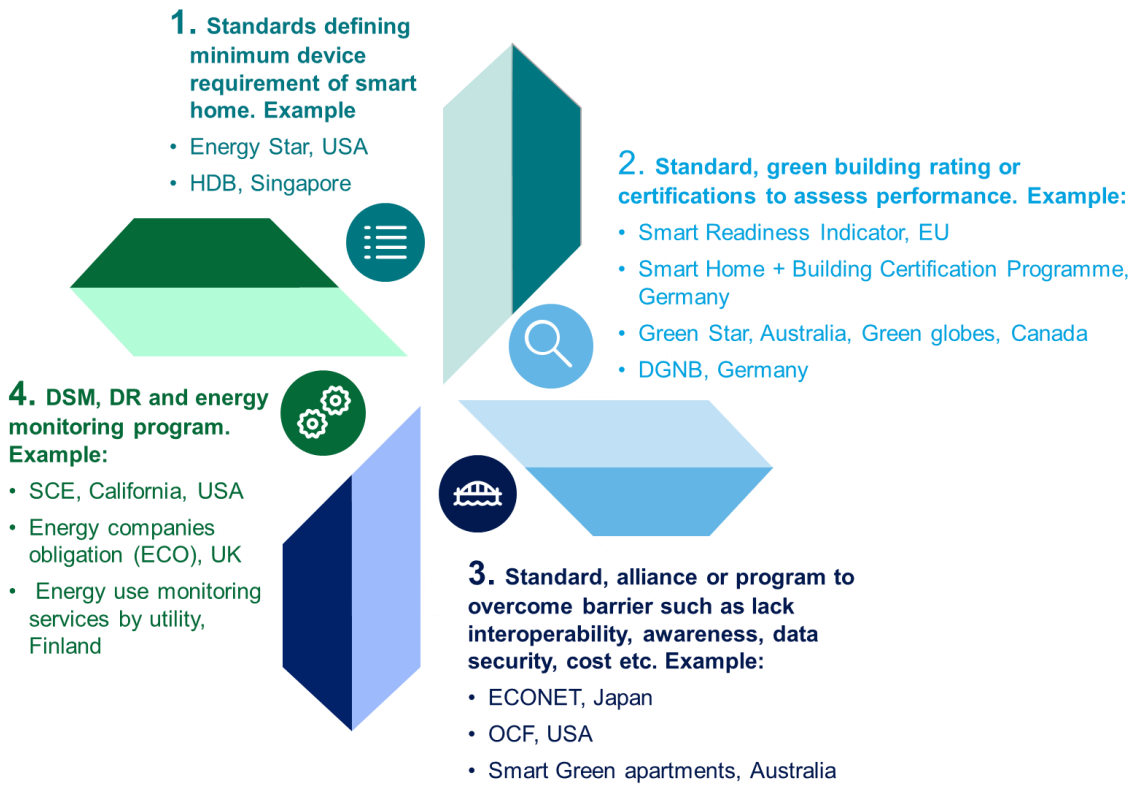


Figure 23 Broad classification of global smart home policies

Details about each of these categories of policies related to smart home and demand response is provided in subsequent section of this chapter.

4.3 Standards defining minimum device requirements of Smart Home

4.3.1 Energy Star[16], USA

ENERGY STAR certified Smart Home Energy Management Systems (SHEMS) are composed of packages of smart home devices and corresponding user services which are accessible through a single platform interface, such as an app. The intent for this specification is to recognize smart home system packages designed to actively recognize and act on opportunities to save energy and help end users manage their energy in a way that saves them money and makes their lives easier. This includes but is not limited to:

- Providing reliable occupancy detection linked to savings strategies that shut off or power down equipment when no one is home,
- Limiting standby power of connected devices, and
- Providing feedback to users about the energy impact of their settings.

User services

A certified SHEMS includes an interface that provides easy recognition and setup of new devices, user control of devices from outside the home, and information on the energy consumption of SHEMS-connected devices. The SHEMS platform receives and responds to occupancy data (e.g. when a home is occupied or not, at minimum) and initiates energy saving device control actions by:

[16] Source: https://www.energystar.gov/products/shems_key_product_criteria

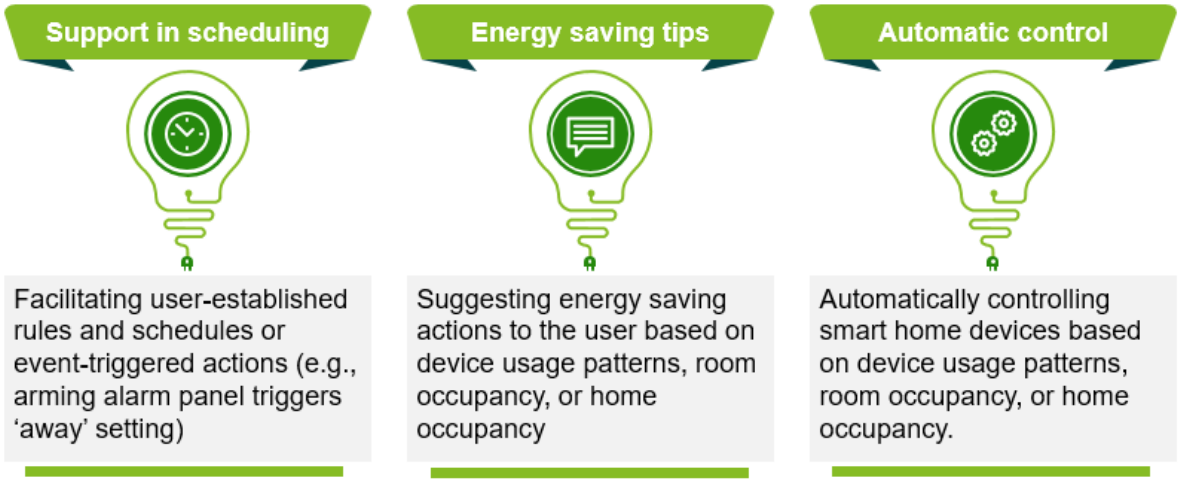


Figure 24 User services of Energy Star

Required devices

An ENERGY STAR SHEMS package includes a minimum bundle of smart home devices specified in table below. Additionally, if none of the devices in the minimum bundle includes a built-in occupancy sensor, a separate occupancy sensing device may be needed to provide an ENERGY STAR SHEMS package.

Table 13 Required devices for Energy Star

Device category	Minimum number of devices	Requirements	Maximum standby power
Connected thermostat	1	ENERGY STAR Certified	3.0 watts
Connecting lighting	2	Must include a minimum of either 2 ENERGY STAR Certified Connected Bulbs or Fixtures or 1 ENERGY STAR Connected Bulb/Fixture and 1 smart light switch capable of reporting energy consumption	0.5 watts for smart light switches
Plug Load Monitor/Control	1	Includes smart plugs, smart power strips, and home energy monitors; must be capable of reporting power or energy consumption.	1.0 watts

Since the ENERGY STAR SHEMS program recognizes combinations of devices and specific services, the ENERGY STAR label is only used in marketing and user materials that associate the required devices with the service platform. Devices (such as smart plugs and power strips) which are not certified under a device-specific ENERGY STAR program are not permitted to be labeled individually with the ENERGY STAR mark.

Additional Capabilities

An ENERGY STAR SHEMS platform, which encompasses all the SHEMS service provider's service offerings, is required to provide the following capabilities:

- Providing a lighting safety mode that automates lighting when activated while home is unoccupied and consumes no more than 0.03 kWh/day
- Controlling devices based on a time of use (TOU) energy price schedule provided by user input or integration with utility programs

- Connecting to a water heater controller or ENERGY STAR connected water heater to enable occupancy-based control of water heating
- With homeowner permission, adjusting the operation of at least one device in response to electric grid requests, while allowing for consumer overrides lasting no more than 24 hours, e.g. a smart thermostat

Unlike the minimum device package and user services, these capabilities are not expected to be enabled in all installations. SHEMS may have additional capabilities described in the Qualified Product List.

Field performance

In order to verify compliance with the above requirements and provide insight into the energy savings performance of SHEMS, service providers must submit statistical data regarding the performance of their ENERGY STAR SHEMS in the field to EPA every 6 months. Because EPA is only collecting statistical data about a service provider's population of installations, EPA will not receive any personally identifiable information associated with individual installations. Similarly, EPA mandates service providers to report relevant cybersecurity and customer privacy standards which their products meet and will make this information available through the list of certified products.

4.3.2 Home Energy Management System, Singapore[17]

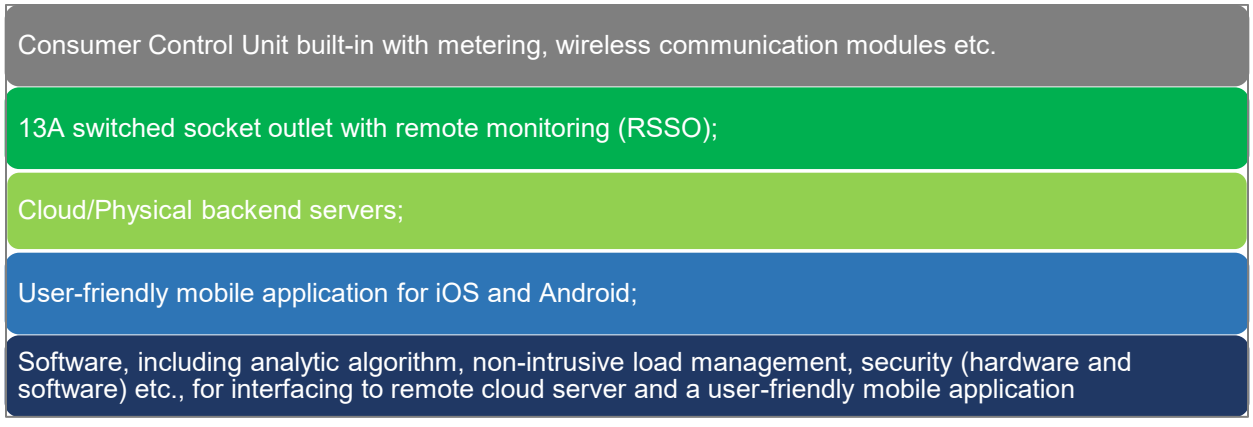
The Standard covers designing, supply, delivery, installation, testing and commissioning of complete work of Home Energy Management System (HEMS). The standard also includes the guidelines for handing over of HEMS in approved working conditions and thereafter maintenance of the equipment (for a period as stipulated in the standard documents) for the complete works of the HEMS. Prior to system commissioning, the Contractor shall conduct and submit a vulnerability assessment for the HEMS, with reference to:

- Annex B of the Infocomm Media Development Authority's (IMDA) IoT Security Guide;
- Common Criteria (CC) or equivalent certification scheme.

The above-mentioned vulnerability assessment and certification ensures the compliance of HEMS devices and components with Singapore Common Criteria Scheme (SCCS), which is a certification compliance for all IT products.

Required devices

As per the standard, the HEMS shall comprise, but not be limited to the following:



[17] Source: Housing & Development Board, Section 81: Supplementary specifications for building works and other installation at Tengah Garden

Components of HEMS standard

The HEMS standard document provides detailed technical specification for required devices and its subcomponents. The list of devices and subcomponents covered in the standard are provided table below. The standard also provides details about the standard acceptance test, testing and commissioning and training to be imparted to users and other stakeholders of HEMS.

Table 14 Components of HEMS Standard Singapore

S. No	Components	Subcomponents / Details
1	Consumer Control Unit (CCU)	• Gateway Unit • Measurement devices/sensors, for circuits monitoring • All electrical accessories & ancillaries, as per tender drawings
2	13A Switched Socket Outlet with Remote Monitoring	• General requirement • Communication • Security
3	Software	• System architecture • Data interface scheme • Non-intrusive load management • Security design • Cloud platform architecture • Mobile app for home automation
4	System acceptance test	• Operational checks where all electrical components and communication modules of the HEMS shall be tested and checked for correct operation. • Functional test on the Consumer Control Unit, RSSOs and the NILM • System checks to ensure successful interfacing to backend, mobile apps etc. • Vulnerability Test • Penetration Test
5	Testing and commissioning	• System checks including checks for continuity for all interconnecting and continuous wiring, insulation check between each conductors and earth, and inspection of termination points for correct jointing of wiring • Network checks to ensure continuous wireless connectivity for the HEMS, with less than 3 working days' downtime • Operational checks where all electrical components and communication modules of the HEMS shall be tested and checked for correct operation • Should any test/demonstration fail during the testing, the Contractor shall arrange for the Testing and Commissioning procedures to be carried out on another suitable date/ time. The Contractor shall carry out rectification works to fulfil the functionality of the HEMS, with all cost to be borne by the

S. No	Components	Subcomponents / Details
		Contractor. This process shall be repeated until the HEMS performs/functions, in accordance with all requirements as stipulated in this document, or approval from S.O. Rep on the completion.
6	Delivery	The Contractor shall ensure that the delivery of the HEMS shall adhere to the building programme, and shall not cause any delay to commencement/completion of construction works
7	Warranty	The Contractor and his Specialists shall warrant the Works on the terms and conditions as stipulated in the Deed of Warranty for the HEMS
8	Documentation and as-built drawing	The Contractor shall provide the Employer the HEMS operation and maintenance manuals in softcopy (pdf format) and hardcopy. The operation and maintenance manuals shall cover, but not limited to, the following: • General description of the HEMS; • Operation principles of the various components in the HEMS; • Setting up and operating instructions for all the equipment and accessories installed; • Frequency and detailed routine maintenance requirements for all the equipment and accessories; • Testing and Commissioning report; • Preventive maintenance checklist; • Software inventory list; • Server workload inventory list; • API endpoint flow map; • Data interface control document; • Vulnerability assessment; • System Penetration Test report; • As-built drawing; • Catalogue, technical data sheets, test certificates of conformity for all the equipment and accessories; • List of the Specialists for all the equipment, accessories and spare parts require for successful operation of the HEMS; and • List of contact detail of the future resident(s) to approach for future maintenance to the HEMS
9	Training	The Contractor shall provide, duration to depend on requirement, free training on how to operate and maintain the HEMS.

4.4 Standard, green building rating or certifications to assess performance

4.4.1 European Energy Performance of Buildings Directive - Energy performance of buildings standards and Smart Readiness Indicator[18]

Buildings are responsible for approximately 40% of EU (single largest energy consumer) energy consumption and 36% of the CO_2 emissions. At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. At the same time, only about 1% of the building stock is renovated each year.

Renovation of existing buildings can lead to significant energy savings, as it could reduce the EU's total energy consumption by 5-6% and lower CO_2 emissions by about 5%. Investments in energy efficiency stimulates the economy, especially the construction industry, which generates about 9% of Europe's GDP and directly accounts for 18 million direct jobs. SMEs in particular, benefit from a boosted renovation market, as they contribute more than 70% of the value-added in EU's building sector.

The building sector is crucial for achieving the EU's energy and environmental goals. At the same time, better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy and the society.

To boost energy performance of buildings, the EU has established a legislative framework that includes the Energy Performance of Buildings Directive 2010/31/EU (EPBD) and the Energy Efficiency Directive 2012/27/EU. Together, the directives promote policies that will help:

- Achieve a highly energy efficient and decarbonised building stock by 2050
- Create a stable environment for investment decisions
- Enable consumers and businesses to make more informed choices to save energy and money

Mentioned directive provides that national authorities must set cost effective minimum energy performance requirements and have these reviewed at least every 5 years. Following the introduction of energy performance rules in national building codes, buildings today consume only half as much as typical buildings from the 1980s.

Both directives (2010/31/EU and 2012/27/EU) were amended, as part of the clean energy for all Europeans package, in 2018 and 2019. In particular, the Directive amending the Energy Performance of Buildings Directive (2018/844/EU) introduces new elements and sends a strong political signal on the EU's commitment to modernise the buildings sector in light of technological improvements and increase building renovations.

Measures to improve the building stock in EPBD

The EPBD covers a broad range of policies and supportive measures that will help national EU governments boost energy performance of buildings and improve the existing building stock. For example

- EU countries must establish strong long-term renovation strategies, aiming at decarbonising the national building stocks by 2050, with indicative milestones for 2030, 2040 and 2050. The strategies should contribute to achieving the national energy and climate plans (NECPs) energy efficiency targets
- EU countries must set cost-optimal minimum energy performance requirements for new buildings, for existing buildings undergoing major renovation, and for the replacement or retrofit of building elements like heating and cooling systems, roofs and walls
- All new buildings must be nearly zero-energy buildings (NZEB) from 31 December 2020. Since 31 December 2018, all new public buildings already need to be NZEB

[18] Source: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

- Energy performance certificates must be issued when a building is sold or rented, and inspection schemes for heating and air conditioning systems must be established. (*covered in detail in energy performance standard)*
- Electro-mobility is supported by introducing minimum requirements for car parks over a certain size and other minimum infrastructure for smaller buildings
- An optional European scheme for rating the 'smart readiness' of buildings is introduced
- Smart technologies are promoted, including through requirements on the installation of building automation and control systems, and on devices that regulate temperature at room level. *(covered in detailed in smart readiness indicator)*
- Health and well-being of building users is addressed, for instance through the consideration of air quality and ventilation
- EU countries must draw up lists of national financial measures to improve the energy efficiency of buildings

In addition to these requirements, under the Energy Efficiency Directive (2012/27/EU), EU countries must make energy efficient renovations to at least 3% of the total floor area of buildings owned and occupied by central governments. National governments are recommended to only purchase buildings that are highly energy efficient.

Energy performance of buildings standards[19]

The set of EPB standards play a key role to support the Energy Performance of Buildings Directive (EPBD) of the European Union. The EPBD aims to promote the improvement of the energy performance of buildings within the European Union, considering outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. (Article 1)

From the amended (2018) text of EPBD Annex 1, point 1: "Member States shall describe their national calculation methodology following the national annexes of the overarching standards, namely ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1, developed under mandate M/480 given to the European Committee for Standardisation (CEN). This provision shall not constitute a legal codification of those standards."

Although the new EPBD does not force the Member States to apply the set of EPB standards, the obligation to describe the national calculation methodology following the national annexes of the overarching standards will push the Member States to explain where and why they deviate from these standards. This will lead to an increased recognition and promotion of the set of EPB standards across the Member States and will have a positive impact on the implementation of the Directive.

Five 'overarching' EPB standards of new EPBD

The EPBD lists five EPB standards as 'overarching'. The meaning of the terms 'overarching' in the new EPBD and in the modular structure of the set of EPB standards only partly overlap. In the modular structure the term overarching refers to the standards that deal with the overall energy performance of a building (module M1), while other modules deal with the building as such (M2) or specific technical building systems or services (M3 etc.). The five 'overarching' EPB standards ISO 52000-1, 52003-1, 52010-1, 52016-1 and 52018-1 have in common that each of these describes an important step in the assessment of the energy performance of building. Details about five EPB standards is provided in table below:

[19] Source: https://epb.center/epb-standards/energy-performance-buildings-directive-epbd/

Table 15 Energy performance of buildings standards

Standard	Details
ISO 52000-1	ISO 52000-1 is the overarching EPB standard, providing the general framework of the EPB assessment. It establishes a systematic, comprehensive and modular structure for assessing the energy performance of new and existing buildings (EPB) in a holistic way. It is applicable to the assessment of overall energy use of a building, by measurement or calculation, and the calculation of energy performance in terms of primary energy or other energy-related metrics. It considers the specific possibilities and limitations for the different applications, such as building design, new buildings 'as built', and existing buildings in the use phase as well as renovation. It also contains an overview of common terms and definitions and symbols for the whole set of EPB standards
ISO 52003-1	ISO 52003-1 provides general insight on how to make good use of the outputs of the set of EPB assessment standards for different purposes (post-processing) in the form of overall and partial EPB indicators. It describes the relation between the EPB indicators and the EPB requirements and EPB ratings. It also includes a couple of possible EPB labels, and it lists the different steps to be taken when establishing an EPB certification scheme.
ISO 52010-1	ISO 52010-1 contains procedures to assess the climatic data needed as common input or boundary condition for many elements in the energy calculations. For instance, as input for energy and daylighting calculations, for building elements (such as roofs, facades and windows) and for components of technical building systems (such as thermal solar collectors, PV panels). But also, as boundary condition for the performance of specific heating, cooling and ventilation systems.
ISO 52016-1	ISO 52016-1 provides the procedures to calculate the internal temperatures and energy needs for heating and cooling for the building as such. This is the core of the calculation of the energy use, because many aspects coincide in this calculation: thermal insulation, air tightness and ventilation, the building mass, solar heat load and passive solar energy and internal heat gains (e.g. from lighting). Many countries have introduced or consider introducing specific EPB requirements at the level of 'the energy needs' of the building or the 'skin' or 'fabric' of the building, independent from the choice of technical building systems and renewable energy systems.
ISO 52018-1	ISO 52018-1 provides an overview of options of indicators enabling (optional) specific EPB requirements (post-processing) at the level of the building as such (building energy needs or building fabric).

Smart Readiness Index (SRI)[20]

The 2018 revision of the European Energy Performance of Buildings Directive (EPBD) aims to further promote smart building technologies, through the establishment of a Smart Readiness Indicator (SRI) for buildings. Article 8 of EPBD, "Technical building systems, electro mobility and smart readiness indicator" establishes a common scheme for rating the smart readiness of buildings.

The indicator provides the "assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance." The smart readiness indicator for buildings aims at raising awareness among buildings occupants, owners, tenants and smart services providers of the value of automation and electronic monitoring of technical building systems as well as providing confidence to occupants about the energy savings provided by these kinds of systems.

[20] Source: Verbeke et al., 2nd technical support study on the smart readiness indicator for buildings, February 2020

More specifically, SRI provides information on the technological readiness of buildings to interact with their occupants and the energy grid. Similarly, it also demonstrates the building's capabilities for more efficient operation and better performance through ICT technologies. By providing a common language for all main stakeholders, the SRI can support the uptake of technology innovation and smart ready technologies through the establishment of a credible and integrated instrument. Some of the advantages of smart building are provided in figure below:

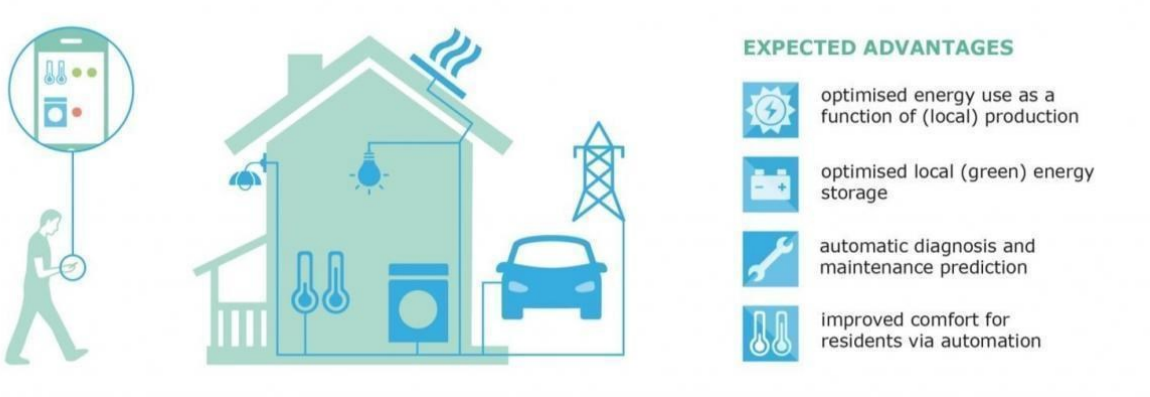


Figure 25 Major benefits of smart building

Key functionalities of Smart Readiness Indicator include:

Figure 26 Functionalities of Smart Readiness Indicator

The Smart Readiness Indicator methodology

The SRI assessment starts with determining which smart ready services are present in a building. These are subdivided into multiple domains. Nine domains considered in SRI are provided in figure below:

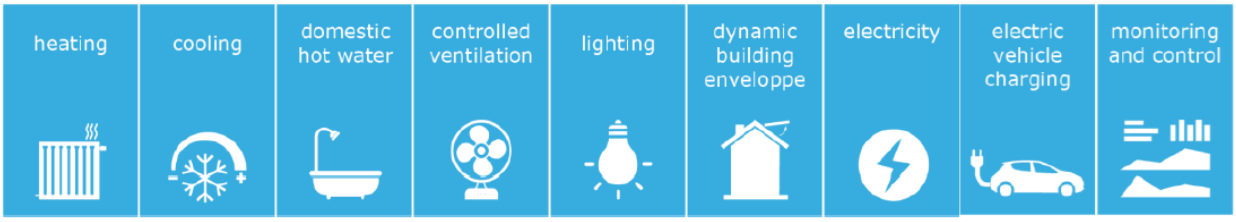


Figure 27 Nine Domains of Smart Readiness Indicator

Subsequently, an evaluation of the functionalities these services can offer is done. Each of the services can be implemented with various degrees of smartness (referred to as 'functionality levels'). Let's take lighting control as an example: this can range from the simple implementation of "manual on/off control of lighting" to more elaborate control methods such as "automatic on/off switching of lighting based on daylight availability", or even "automatic dimming of lighting based on daylight availability".

After the services present in a building are determined the impact score is assessed based on various impact criteria. Seven impact criteria considered for SRI are provided in figure below:

Figure 28 Seven Impact Criteria of Smart Readiness Indicator

Based on a checklist these impacts and functionalities are then aggregated into an overall score displaying the smart readiness of a building. The result can be presented as an overall single score, as a relative score (e.g. indicating that a building achieves 65% of its potential smartness impacts) or as a label classification (e.g. SRI label class 'B'). Sub-scores can also be presented (e.g. 72% on energy savings and 63% on comfort).

4.4.2 Smart Home and Building Certification Programme, Germany[21]

In the "Smart Home + Building Certification Programme", a new approach to conformity assessment for Smart Home products is being developed. Attention is paid both to interoperability and to IT security. The aim is to offer manufacturers testing of corresponding products and the issue of a seal of quality with which market confidence in the technology offered can be strengthened. Over and above this, measures are being devised for further mobilization of the Smart Home market and a Smart Home Community covering various industries is being established.

The objective of the project is to develop an open networking strategy based on generally accepted standards as a bridging technology. It is to integrate the large number of existing and successful systems and communications standards, and to be capable of embedding the modern all-IP based systems of the present and future. The test procedure developed in the project will serve as the basis for the examination and verification of technical feasibility in terms of interoperability, IT security and data protection. Furthermore, measures for further mobilization of the Smart Home market are to be devised and a Smart Home Community covering various industries to be established. Details about the innovation expected with the certification program vis-à-vis present situation is provided in table below:

Table 16 Innovation with Smart Home + Building Certification Programme, Germany

To date	With the Certification Programme
Manufacturers mostly only have points of orientation from their own industry or system in the development of Smart Home solutions.	Suppliers will be able to follow open standards for cross-system interoperability and IT security.
Users have no suitable aid to orientation in the selection of compatible Smart Home solutions from different suppliers.	The planned Smart Home ready seal will create transparency on the market for dealers, crafts persons and final customers. The seal will indicate which systems can be combined interoperability and with IT security. The seal offers manufacturers the opportunity to differentiate themselves on the market.

[21] Source: German Standardisation Road Map – Smart Home + Building, Version 2.0 (August 2015)

To date	With the Certification Programme
Cross-industry networking of the different stakeholders on the Smart Home market has not progressed very far	The project will bring about an expansion of the Smart Home community, facilitating an exchange of ideas and experience between all the relevant stakeholders on the Smart Home market.

4.4.3 Green building rating systems

Based on desk review, project team found guidelines/mandate regarding automation in green building ratings that are prevalent across the globe, which includes LEED, Green Globes (Canada), Green Star (Australia), Green Mark (Singapore), BREEM (UK) and DGNB (Germany), Energy Conservation Building Code (ECBC), GRIHA and IGBC. List of broad points covered in mentioned rating system regarding automation in buildings are as follows. The green rating system includes guidelines about monitoring and control of

- Lighting system including dimming
- Energy and water usage in building using smart meters
- HVAC system
- Indoor Air Quality

Brief about the guidelines related to automation, provided in green building rating system, is provided in table below. Details about Energy Conservation Building Code (ECBC), GRIHA and IGBC are provided in subsequent chapter.

Table 17 Automation in green building rating systems

Rating System	Category	Subcategory	Description in the rating system
LEED - USA	Water Efficiency	Outdoor Water Use Reduction	Talks about smart scheduling Technologies
	Energy and Atmosphere	Advanced Energy Metering	The data collection system must use a local area network, building automation system, wireless network, or comparable communication infrastructure.
		Demand Response	Install interval recording meters with communications and ability for the building automation system to accept an external price or control signal.
	Indoor Environmental Quality	Minimum Indoor Air Quality Performance Required	Monitor carbon dioxide (CO2) concentrations within each thermal zone. CO2 monitors must be between 3 and 6 feet (900 and 1 800 millimeters) above the floor and within the thermal zone. CO2 monitors must have an audible or visual indicator or alert the building automation system if the sensed CO2 concentration exceeds the set point by more than 10%. Calculate appropriate CO2 set points using the methods in ASHRAE 62.1–2010, Appendix C.

Rating System	Category	Subcategory	Description in the rating system
	Performance Metering and Monitoring	Smart Metering & Monitoring	Ensure the installation of smart metering1 system (as given in Table 10.5) which is capable of tracking energy and water consumption through a web-hosted portal for all meters mentioned in Appraisal 28.1.1 All smart metering and monitoring systems should be capable of the following: - Hourly data reporting in near real-time (no more than 15-minute delay) - Energy mix breakdown and consumption patterns - Water consumption patterns from various sources - Ability to set energy and water consumption targets, alarms, and pricing - Ability to compare historical trends and benchmark data - Real-time monitoring with user interface that operates even on mobile devices
	Occupant Comfort	Appendix 4D: Strategies for improved IAQ	Carbon dioxide or air quality sensors may be used to check the level of pollutants in the occupied space and indicate to the **building management system** to control the opening of outside air dampers, thereby effectively providing ventilation on demand. A demand-controlled ventilation system uses a variable speed drive based on the opening and closure of the fresh air dampers, controlled by the carbon dioxide sensors
Green Star - Australia	Metering & Monitoring	Monitoring system	**6.1.2 Automatic Monitoring System** Set provision of providing automatic monitoring systems that record both consumption and demand of energy or water, and can produce reports on hourly, daily, monthly, and annual energy use for all meters. The installed meters must be capable of producing an output that can be transmitted to a central location (either onsite or offsite). This central location must provide data retrieval and reporting mechanisms. As a minimum, the automatic monitoring system must be capable of: · Collecting data from all meters; · Alerting to missing data due to failures; · Recording energy use and water consumption, and providing a reporting capability at user adjustable intervals; · Raising an alarm when the energy or water use increase beyond certain parameters and automatically and instantly issue an alert the facilities manager. ||The process to assess, correct and validate alerts or faults must be detailed and contained in an accessible location;||R2.06.02 · Providing a breakdown of the information by building system (mechanical, electrical, etc.), or by space (or by tenanted floor); · Including the consumption water or energy, the load versus time (load profile), and the power factor (in the case of energy); and · Producing, as a minimum, a quarterly report that is automatically emailed to the facilities manager responsible for the building.
	Indoor Environmental Quality	Visual Comfort	Gives provision of Automated Blinds
	Energy	Greenhouse gas reduction	Automated lighting control systems, such as occupant detection and daylight adjustment, are provided to 95% of the nominated area

Rating System	Category	Subcategory	Description in the rating system
	Innovation	Refrigerant Impact	Talks about automatic leak detection system and automated refrigerant recovery system
Green Mark - Singapore	Resource Stewardship	Water Efficiency Measures	Provision of water efficient automated irrigation system with sensor control
	Smart and Healthy Building	Smart building operation Data Control	Encourage adoption of automated controls in managing energy/ resources consumption in the common areas - Provision of timer sensors/ controls for lighting and ventilation systems in community spaces such as link buildings, community halls etc. - Provision of Bi-level motion sensors for artificial lighting systems in >80 % common area
		Smart building operation Integration and Analytics	Encourage innovative and integrative use of sensor and motion data for optimizing or attaining persistence of high performance and energy efficiency of the residential development - Provision of website or/and accessible readout - Provision of energy portal and/or dashboard
	Advanced Green Efforts	Smart Water Management System	Provision of smart water management system in which system/device allows homeowners to access own water uses
		Smart Building Operations And Smart Building Information Modelling (BIM)	- Car park data collection system with open protocol support for lighting/space control - Integration of systems for energy savings, etc. - Mobile application for monitoring / controlling of electrical / water consumption
Green Globes - Canada	Project Management	Commissioning	Building Automation Systems (BAS)
	Energy	Lighting	Interior Automatic Light Shutoff Controls Automatic lighting photocell controls which include stepped switching, stepped dimming, and continuous dimming.
		HVAC Systems and Controls	Building Automation System (BAS) that encompasses all systems that affect building energy performance, lighting, and thermal comfort
		Metering	Sub-meters installation, which should either report automatically to the building automation system
		Irrigation	Water Sense/Smart Water Application Technology (SWAT), smart controllers (ET, rain sensors, or soil moisture sensors), and automatic rain shut off devices
BREEAM - UK	Health and Well Being	Indoor Air quality	Areas of the building subject to large and unpredictable or variable occupancy patterns have carbon dioxide (CO_2) or air quality sensors
	Energy	Energy Monitoring	Include automatic meter reading systems and building energy management systems (BEMS) Provision of automatic control to prevent operation during daylight hours including presence detectors, time switches, daylight sensor etc.
	Water	Water leak detection system	Provision of a permanent automated water leak detection system that alerts the building occupants to the leak or an inbuilt automated diagnostic procedure for detecting leaks

Rating System	Category	Subcategory	Description in the rating system
	Pollution	Impact of refrigerants	Provision of permanent automated refrigerant leak detection system
	Management		Provision of Central Control System and Building Management System
DGNB - Germany	Socio - Culture & Functional Quality	Thermal Comfort	Talks about Automatic Door System
		Indoor Air quality	Provision of CO2 sensors
		Visual Comfort	Automatic adjustment of visual light
		User Control	Temperature adjustment for every living space by means of a central control system/smartphone
	Technical Quality	Use and integration of building technology	Provision of Building Automation and refers following guidelines for requirement of technical equipment room : - DIN EN ISO 16484 Building automation and control systems (BACS) and/or EN 13321-1 Open data communication in building automation, controls and building management and/ or EN 13779 Performance requirements for ventilation and air-conditioning systems.
		Lighting control	Requirement of at least 80% of all illuminants or lights with an external impact are switched off or dimmed automatically or are equipped with motion sensors.

4.5 Standard, alliance or program to overcome barriers

To promote use of smart home automation technologies among consumers, a few countries have taken several initiatives and devised policies to overcome barriers to adoption of home automation technologies. To identify international best practices for market transformation and recommendations to overcome the identified barriers to adoption of smart home technologies, the project team undertook extensive literature review. List of the international best practices and the barrier addressed by them is provided in figure below:

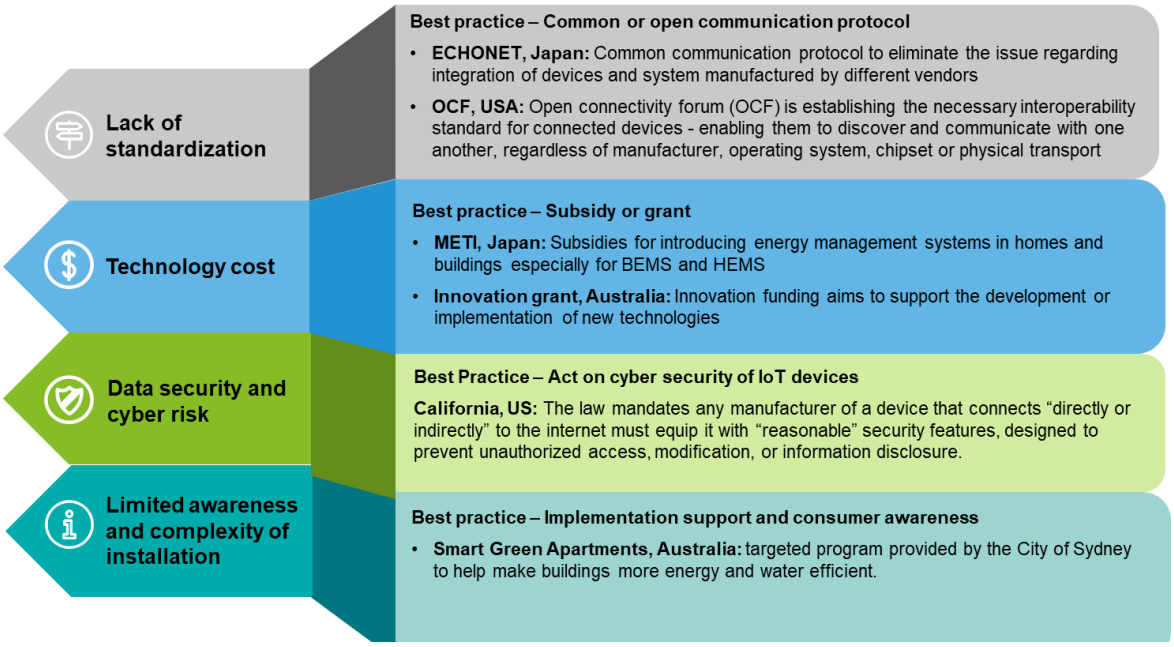


Figure 29 Barriers and international best practices on market transformation

Brief about some of the global best practices are provided in table below:

Table 18 Barriers and International best practices on market transformation

Country	Initiative	Targeted barrier	Details	Targeted areas
Japan	ECHONET	Lack of standardization	Common communication protocol to eliminate the issue regarding integration of devices and system manufactured by different vendors	This Japanese communication protocol helps in connecting 8 product segments that includes • smart meters, • photovoltaic solar panels, • storage • batteries, • fuel cells, • gas/oil water heaters, • air conditioning, • lighting equipment and • EV chargers As of February 2015, ECHONET supports over 90 type of equipment and compatible product in above mentioned 8 product segments
	Subsidy for HEMS and BEMS	Technology cost	Specifically, for BEMS and HEMS, METI (Ministry of Economy, Trade and Industry) provides subsidies for introducing energy management systems in homes and buildings	HEMS and BEMS helps in managing the energy consumption of appliances such as lighting, air-conditioning, and hot-water supply by using information technology systems. These systems enable automatic management of several appliances simultaneously, leading to energy savings and reduced environmental impact. Currently the BEM and HEMS subsidy program is implemented by Sustainable Open Innovation Initiative (SII) under the budget of METI
US	Act on cyber security for IoT devices	Data security and cyber risk	State of California has become the first US state with an Internet of things cyber security law. Starting on January 1st, 2020, any manufacturer of a device that connects “directly or indirectly” to the internet must equip it with “reasonable” security features, designed to prevent unauthorized access, modification, or information disclosure.	A manufacturer of a connected device shall equip the device with a reasonable security feature or features that are all of the following: ▪ Appropriate to the nature and function of the device. ▪ Appropriate to the information it may collect, contain, or transmit. ▪ Designed to protect the device and any information contained therein from unauthorized access, destruction, use, modification, or disclosure. Subject to all of the requirements of subdivision (a), if a connected device is equipped with a means for authentication outside a local area network, it shall be deemed a reasonable security feature under subdivision (a) if either of the following requirements are met: ▪ The preprogrammed password is unique to each device manufactured.

Country	Initiative	Targeted barrier	Details	Targeted areas
				• The device contains a security feature that requires a user to generate a new means of authentication before access is granted to the device for the first time.
Australia	Smart Green Apartments	Limited awareness and complexity of installation	Smart Green Apartments is an award-winning, targeted program provided by the City of Sydney to help make buildings more energy and water efficient.	Each participating applicant receive: • energy and waste assessments and action plans (including NABERS rating) • costed upgrade recommendations • online data portal • training and networking opportunities • Implementation support. Till date 170 buildings have participated in this scheme and are saving thousands of dollars each year on running and maintenance costs.
	Innovation grants	Technology cost	Innovation funding aims to support the development or implementation of new technologies or processes that are currently not being used in the local market but have the potential to reduce greenhouse gas emissions and improve efficiencies that could be applied across our area.	Funding under the innovation funding stream is available in 2 categories: • Feasibility studies that investigate innovative environmental solutions with the potential to improve environmental performance across a range of buildings and facilities in Sydney. Up to $20,000 is available in this category, with support to be matched by 25% or more cash or value in-kind from the applicant. • Demonstration projects that implement solutions to reduce resource consumption and can be rolled out at scale. Up to $80,000 is available in this category with funds to be matched by 50% or more cash or value in-kind from the applicant.
USA	Open connectivity foundation (OCF)	Lack of standardization	Open connectivity foundation (OCF) is establishing the necessary interoperability standard for connected devices - enabling them to discover and communicate with one another, regardless of manufacturer, operating system, chipset or physical transport **OCF missions are:** • Provide specifications, code and a certification program to enable manufacturers to bring	**OCF Provides Manufacturers and Developers With:** • A framework for secure interoperability for multiple OSs, platforms, modes of communication, transports and use cases. • OCF Bridging Specification for discovery and connectivity into other ecosystems. • OCF Security Framework and identification mechanisms. • Opportunity for innovation, product differentiation and faster time to market. **OCF Certified Products Provide End Users With:** • A choice of products that aren't dependent on one particular brand to all work together.

Country	Initiative	Targeted barrier	Details	Targeted areas
			OCF Certified products to the market that can interoperate with current IoT devices and legacy systems. • Make the end user's experience better by seamlessly bridging to other ecosystems within a user's smart home and ensure interoperability with OCF compliant devices	• Products that just work, and security that is counted on. • The ability to create a customized experience. • An Internet of Things experience that improves everyday life.

4.6 DSM, DR and energy monitoring program

Demand Response can be defined[22] as "the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market whether alone or through aggregation". Conceptually, DR is a flexibility service that is specified by direction, size, time and location. Demand response program generally classified in two board categories which include incentive-based program and price-based program. Brief about mentioned categories and subcategories are provided in figure below:

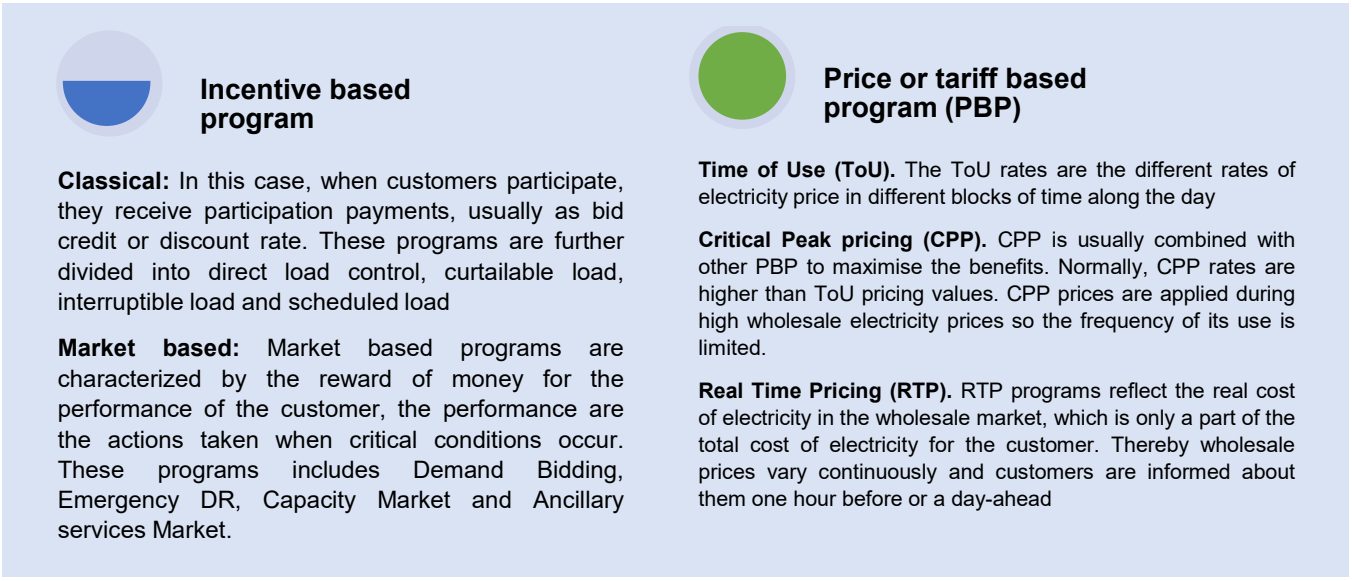


Figure 30 Types of Demand Response program

This section provides brief about some of the demand side management, demand response and energy monitoring program implemented by utilities across the globe to manage the electricity demand of residential consumers. Brief about some of the demand response, DSM and energy monitoring program are provided in table below:

[22] Source: The Electricity Directive (EU) 2019/944.

Table 19 DSM, DR and energy monitoring program

Program name	Utility	Program type	Program details	Benefits to consumer
Smart Energy Program – smart thermostat	South California Edison (SCE).	Manual demand response	• During an energy event, SCE notifies consumer to temporarily adjust the temperature setting using smart thermostat up to four degrees to limit A/C usage in home. • An SCE Energy Event is a designated period of time when SCE limits A/C usage in participating homes to reduce demand on the energy grid. • Energy events can be called anytime throughout the year but can't exceed more than four hours in one day. Multiple events can be called in one day, but the total cannot exceed a maximum of four hours per day • A smart thermostat connects the heating and cooling systems to user's smartphone, smart speaker, or other device. Depending on the thermostat, user can schedule your temperature settings, change the temperature remotely (based on demand response event), and it can remind user about scheduled maintenance. Some smart thermostats also use machine-learning to understand user heating and cooling preferences and then adjust settings based on those learnings.	• Sign up benefit: $75 bill credit by enrolling in the Smart Energy Program • Up to $40 in bill credits yearly for participating in the program from June 1st through September 30th.
Summer discount plan – Maximum saving cycle	South California Edison (SCE)	Automatic demand response	• When user voluntarily sign up, utility install a remote-controlled device on or near user air conditioner at no cost to user. This will allow utility to turn off or cycle A/C unit during energy events throughout the year based on the user program preferences. In this program user can earn bill credits from June 1 to October 1 for participating. • A/C may be shut off for up to 6 hours/day • If user is eligible for the override option, user can override an event by making the change on the utility installed remote	• Any number of energy events per year. No override. Savings up to $140 • User can override up to 5 days per year. Saving up to $70

Program name	Utility	Program type	Program details	Benefits to consumer
			controlled device. Once user enable the override option, there will not any more energy events that day.	
Summer discount plan – Maximum comfort cycle	South California Edison (SCE)	Automatic demand response	• When user voluntarily sign up, utility install a remote-controlled device on or near user air conditioner at no cost to user. This will allow utility to turn off or cycle A/C unit during energy events throughout the year based on the user program preferences. In this program user can earn bill credits from June 1 to October 1 for participating. • A/C may be shut off for 15 minutes each half hour for up to 6 hours/day • If user is eligible for the override option, user can override an event by making the change on the utility installed remote controlled device. Once user enable the override option, there will not any more energy events that day.	• Any number of energy events per year. No override. Savings up to $70 • User can override up to 5 days per year. Saving up to $35
Energy companies obligation (ECO)	All utilities in England, Wales and Ireland	Energy efficiency	• The scheme provides free or subsidized energy saving home improvement. The scheme was set up for the largest energy suppliers to help make British households more energy efficient and support those in society most in need. • Energy efficiency products or services available under the program are loft insulation, cavity insulation and energy efficient boilers • The program started in 2013 and presently active as ECO3	• Reduction in utility bill due to improved energy efficiency and reduction in energy losses • Improvement to insulation and installation of energy efficient heating system is done for free or subsidized rate
Demand response program - Curb Your Power	Powershop Australia	Manual demand response	• The Program is an opt-in program where customers are notified (initially via SMS or Powershop mobile app) to curtail their electricity usage during times of peak demand. • Powershop customers can register to participate in CYP by completing an online registration form on Powershop website. • The Program is entirely voluntary and certain customers are excluded from	• Residential customers receive a $10 power credit if they hit their ‘curb target’. The power credit can be used by customers to purchase electricity with Powershop. • The minimum curb target for a residential customer is 10% reduction from their

Program name	Utility	Program type	Program details	Benefits to consumer
			participation (e.g. vulnerable customers). • Once the opt in consumer is notified about peak event, consumer may reduce the electricity demand by: ✓ switching off non-essential loads such as AV systems, ✓ Switch off idle running devices ✓ Alter HVAC temperature using thermostat ✓ Other options	baseline or reduction of 1 kWh every hour of the Event. • Incentive structure: ✓ 10% or 1 kWh - $10 ✓ 2 to 5 kWh - $ 20 ✓ 5 to 10 kWh - $ 50 ✓ 10 to 20 kWh - $ 100 ✓ 20+kWh - $ 200
Demand response program – Peak energy rewards	AGL Australia	Manual Demand response	• The Program is an opt-in program where customers are notified via SMS or email to curtail their electricity usage during times of peak demand. • The Program is entirely voluntary • About 700+ residential consumers participated in four Peak Events from January to April 2018 on business days when the forecast temperature was above 30°C. • The communication process for summer 17/18 Peak Events was: ○ A SMS message 24 hours before the event ○ A reminder SMS message 15 – 30 minutes before the event start, with a link to AGL website for energy reduction tips ○ A final SMS message immediately after the event, thanking the customer and with a link for a quick post event survey (which asks about participation, actions and comfort) ○ An email 2 – 7 days after the event with the performance outcome (calculated using AGL's baseline methodology), confirmation of the reward for the event and accumulated rewards for all events to-date.	• Incentive structure comprising a one-off $50 to sign up, and an event reward of $2 for each kWh reduced calculated from the customers baseline energy use.
Power2U	Ausgrid	Energy efficiency	• The Ausgrid Power2U Project offers incentives to customers to permanently	• The project offers participating customers a way to save money, reduce

Program name	Utility	Program type	Program details	Benefits to consumer
			reduce their electricity use on Ausgrid's network. • The incentives offered in four select areas encompassing 17 suburbs in the Sydney area and will focus on encouraging customers to implement new solar power systems and efficient lighting retrofits. • This project seeks to demonstrate that demand management can delay or avoid replacement of aged network assets.	their emissions and ultimately share their energy via the grid. • Further, the program offers ARENA and the City of Sydney an alternative pathway to increasing renewable electricity supply on the grid.
Energy use monitoring services by utility	Caruna, Finland	Energy efficiency, DSM	In this energy monitoring service, consumer can monitor the electricity consumption by year, month, week, day of the week or hour. The monitoring service helps in finding out how much electricity is consumed in home and how consumer have succeeded in saving electricity. Electricity consumption data is updated in the service the following day. Energy monitoring is free of charge, and it is available in Finnish, Swedish and English 24 hours a day	Using energy monitoring service, consumer can compare various electricity distribution products. The product comparison helps consumer find out which electricity distribution product is the best value option for them. For instance, with nighttime distribution plan, consumer having electric heating system, can operate storage heaters or a central heating system (with thermal storage, such as underfloor heating or radiators using hot water circulation) during nighttime when electricity is available at reduced price.
Savel reporting service	Helen Limited, Finland	Energy Efficiency, DSM	In this free Sävel service, consumer can monitor the energy consumption of home or company on hourly, daily or weekly basis	This helps consumer to plan and cut down on the energy use

Review of international best practice in smart home domain has provided a potential list of interventions which may applicable for Indian smart home market. In next chapter, potential recommendations to overcome barriers to adoption of smart home devices in Indian potential areas of interventions have been identified and analysed to develop a national policy road map for promotion of smart home technologies in India.

5. National policy road map

5.1 Background

Based on survey and interviews of stakeholders covering consumers, manufacturers, system integrators, builders, architects, service providers etc. (conducted as part of the baseline assessment of Indian Smart Home Market), key barriers to adoption of smart home automation products and services were identified. List of barriers to adoption of smart home devices are:

- Limited awareness among consumers regarding energy savings and Return on Investment (RoI)
- Cost of acquisition of technology
- Absence of relevant data privacy and cyber security policies
- Absence of product testing and certification facilities
- Absence of product regulation including interoperability
- Absence of mandate for builders for home automation
- Absence of case studies based on locally available data
- Absence of nudges, gamification etc. for generating consumer interest

Methodology followed for preparation of national policy roadmap is provided in figure below:

Figure 31 Methodology for preparation of national policy road map

To propose recommendations and interventions to overcome these barriers, a structured approach has been adopted through:

- Identification of international best practices across regions and geographies
- Suggestions from stakeholders through individual consultation
- Inputs from national and international subject matter experts (SMEs)

Based on above, several recommendations were derived which may prove to be instrumental in improving the penetration of smart home devices in Indian residential sector.

To shortlist and prioritize identified recommendations, project team used Multi Criteria Decision Analysis (MCDA). The MCDA is generally used in addressing various policy problems i.e. for deciding ‘which policy measure to start with’ given the range of measures available. Project team also used network analysis along with MCDA, as this methodology not only considers the internal properties of the measures but also

their interactions with other potential measures. The steps of MCDA followed by project team is provided in figure below

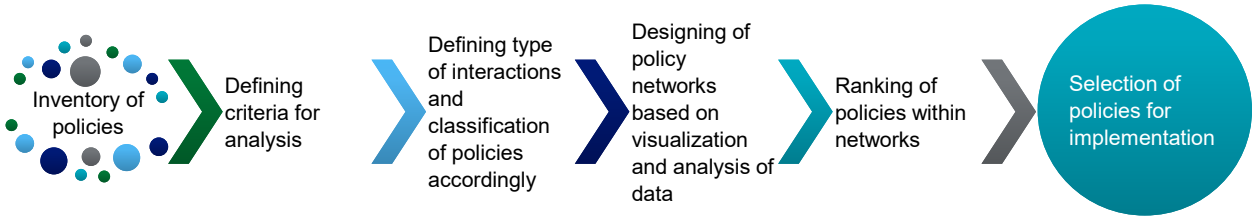


Figure 32 Methodology for shortlisting and prioritizing recommendations

5.2 Recommendations/proposed interventions

To overcome the barriers mentioned in previous section, there is a requirement of interventions at multiple fronts. Based on the expected timeline of implementation the recommendations can be classified as short, medium and long term. Figure providing brief about short, medium and long terms interventions is provided below:

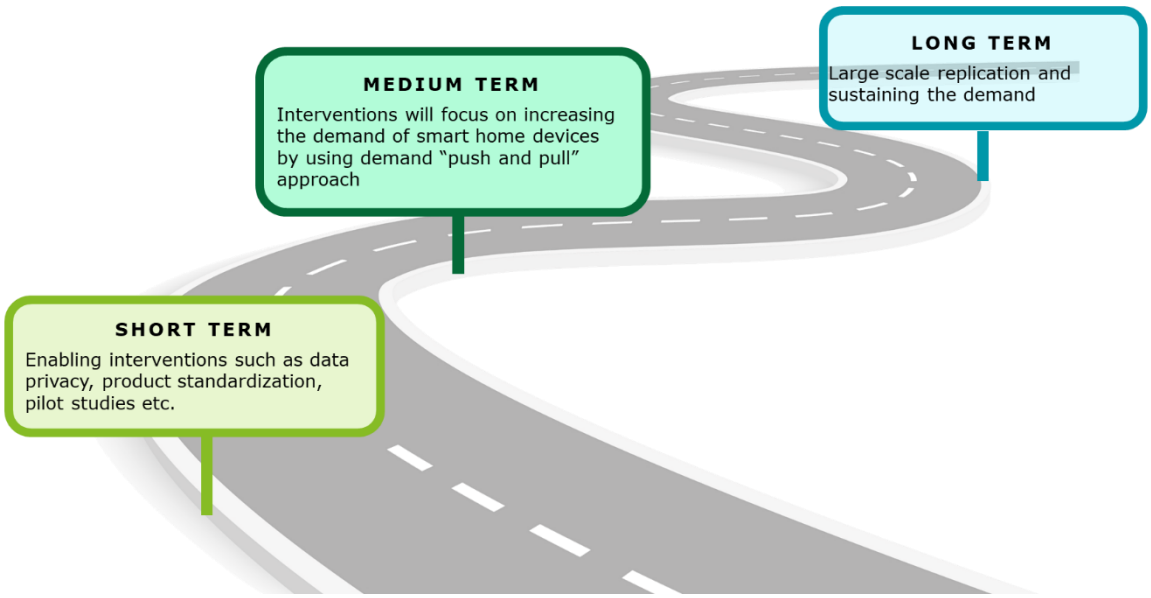


Figure 33 Classification of recommendations of national policy road map

Short term interventions (1 year to 3 years) are prerequisite for establishment of a reasonable smart home market in India, therefore interventions of short term may be termed as the enablers of smart home market. This broadly includes product standardization (to address interoperability issue), data privacy and cyber security, awareness creation and other enabling recommendations.

In medium term (3 years to 7 years), to further increase the penetration of smart home devices, the interventions should focus on increasing the demand of smart home devices by using both demand "push and pull" approach i.e.:

- To create a demand, pull from consumers for smart home devices (due to visibility on energy saving or incentives in form of demand response) and
- To provide a demand push by promoting use of smart home devices in new and existing homes through awareness creation and policy support.

In long term (7 years to 10 years), to sustain the growth in smart home market, interventions should focus on making smart home device a mandatory requirement in new homes (with sanctioned load more than a threshold value) and by developing innovative business models. List of recommendations identified, and broad classification based on the area of intervention is provided in figure below:

Area of intervention	Recommendation
Data security and interoperability	• Policies and protocol for product standardization • Policy on cyber security and data privacy • Certification of Smart Home device/service to ensure compliance of interoperability
Testing facility	• Defining testing standards for smart home devices and use of existing facilities for testing • Establishment of new testing facilities based on market growth
Pilot Studies	• Pilot studies on sample smart homes to estimate energy saving potential and to define minimum device requirements. • Implementation of pilot project for demand response aggregator model for sample smart homes.
Awareness	• Capacity building of integrators, builders and architects • Inclusion of section on home automation in energy auditor certification course • Inclusion of automation of technologies in university course curriculum • Development of web tool for users for enable selection of smart home devices • Launch of industry supported outreach programs (similar to CFL & LED adoption) including development of regional experience centres for consumers • Capacity building of DISCOMs on Demand Response in Residential Sector using smart home devices
Functionality and technology cost	• Defining and regular updation of minimum device requirement to make a home smart and demand response ready • Development of ESCO based program for large replication based on product or service model
Policy Support	• Inclusion of smart home requirement in Eco Niwas Samhita (ENS) • Inclusion of automation as requirement in relevant appliance S & L protocol • Scheme for certification/ labeling of homes as Smart Energy Homes, a prereqisite for Demand response • Scheme to support to real estate developers to comply with ENS mandate on smart home devices
Support for Demand response	• Amendment of existing DSM regulations to include development of DR program as responsibility of Discom • Support for development of standard Demand Response program for utilities • Development of scheme for empanelment and certification of DR aggregators to promote DR as source of electricity • Design scheme for integration of demand response and distributed energy sources with electricity exchange as source of electricity • Development of scheme to provide micro carbon credits to consumers on utility bill for energy saving and load shifting using smart home devices

Figure 34 Recommendations of national policy road map

Brief description of above recommendations is given in subsequent paragraphs.

Product standardization

- **Policies and protocol for product standardization:** Standardisation of smart home devices is one of the most important prerequisites for growth of home automation market in India. During survey of consumers; issue of interoperability identified as the main barrier to adoption and growth smart home ecosystem. It is therefore recommended that a guidelines or policies for Standardisation of smart home products should be rolled out by concerned government department to ensure devices from different OEMs can connect, communicate and function as intended to deliver control, comfort and energy savings. For selecting a standard for universal use, following things should be considered:
    - ✓ The standard should be futuristic i.e. it should be compatible or upgradeable with hardware SOCs (system on a chip) and software of future.
    - ✓ The communication standard has enough signal strength to meet requirement of smart home devices and should not interfere with other systems.
    - ✓ The power requirement for communication, standby operation is on lower side to conserve energy.
- **Policy on cyber security and data privacy**: Size, complexity and cost of smart home devices reduced due to shifting of complex and dynamic computing from device itself to an external cloud computing system. Barring limited applicability of wired automation (in highly customized system), most of the smart home use wireless communication. Communication over wireless medium, internal as well with cloud, makes the smart home devices susceptible for data theft and cyber-attacks. To ensure data privacy and cyber security, it is recommended that concerned government department should develop privacy protocols or guidelines specific to need of smart home devices
- **Certification of Smart Home device/service:** Once the interoperability guidelines or protocols is in place, there would be a requirement of certification to provide consumers an information about interoperability compliance. Therefore, it is recommended to develop a scheme to certify smart home devices and services to ensure interoperability and compliance with energy efficiency standards (i.e. to minimize standby power consumption). Details of certification, probable list of concerned stakeholders, role and responsibilities is provided in implementation framework section 5.4.

Testing facilities

Testing facilities generally require three things for providing testing services that includes testing apparatus, skilled professionals and testing standards. A number of laboratories in India, are catering to testing requirements of America and EU countries (for GDPR, CCPA), therefore skill set and testing apparatus is present. **For India to move forward we need standards for testing**, this will enable the existing or new laboratories to provide services to test smart home products as per the defined standard. To ensure sector wide availability of testing facilities, following guidelines should be in place:

- The laboratory should provide testing facility to multiple brands
- The laboratory should be governed by strong data privacy and intellectual property rights rules.

Pilot Studies

One of the major barriers identified based on the baseline assessment (conducted as part of this assignment), is limited consumer awareness and ambiguity about RoI (i.e. how smart energy home product/service leads to energy and cost saving). Also, at present, there is lack of data regarding energy saving, demand response and cost saving potential of smart home devices in local conditions as not many field studies has been undertaken in India.

To overcome the barriers to adoption of smart home devices such as ambiguity about RoI, lack of data on energy and cost saving (and demand response potential in local context) and to understand consumer response to smart home devices, it is recommended to undertake pilot study in India on smart home devices.

Pilot studies may enable understanding of optimal strategies for encouraging adoption of smart home automation through building energy efficiency schemes/policies such as Residential Energy Labelling Program, Eco-Niwas Samhita etc. Main objectives of pilot study can be:

- To estimate energy saving, demand response and cost saving potential of smart home devices
- To test benefits and limitations of using home automation technologies to make building energy efficiency policies more receptive to smart, demand response energy supply systems
- To assess the aspects such as ease of installation, ease of use and consumer response regarding smart home devices.

Functionality

Defining minimum device requirement for smart home: Smart home devices are a set of equipment that provides connectivity and control feature to home appliances. To enable the user to schedule, control and operate select home appliance from anywhere, a set of minimum smart home devices are required. This minimum set is also essential to provide required communication and control option to make the home eligible to participate in utility run auto- demand response program. This intervention may help user in:

- Saving energy by prevention of idle running of appliances
- Saving cost by operating appliance when electricity tariff is lowest and
- Shifting of non-critical load from peak to off peak team to prevent purchase of costly electricity by utility and to reduce grid congestion.

Policy Support

To promote growth of smart home devices in India following policy interventions are recommended:

- **Inclusion of control and automation in Standard and Labeling program**: Standard and labeling program have been successful in providing consumers an informed choice by energy efficient appliances by clearly indicating the efficiency level using number of stars. To promote use of automation technologies in home appliances, it may be included in standard and labeling guidelines during next update. The appliance with smart features may be labelled with an “c” as suffix to star rating to highlight the connectivity and control aspect.
- **Inclusion of Smart Home Requirement in ENS:** Energy codes for new buildings are an important regulatory measure for ushering energy efficiency in the building sector. They are particularly relevant for countries like India where the building stock is growing rapidly. Given the current and anticipated rapid growth in the residential building stock across India and the consequent opportunities as well as the necessity for energy conservation in this sector, the Energy Conservation Code for Residential Buildings (known as ECO Niwas Samhita) is established by the Ministry of Power in 2018. To promote use of home automation, it is recommended that installation of basic or minimum smart home device (as covered in functionality aspect above) should be included as a requirement in Eco Niwas Samhita. Home automation can be included initially as voluntary requirement and in long run may become mandatory for homes with connected load more than certain threshold value.
- **Certification of home as smart**: Benefits of smart home devices such as prevention of idle running, fine tuning of operating parameters (according to consumer needs) and demand response, can be accrued once a minimum set of smart home devices are installed and actually perform as

intended. To ensure installation and effective operation of smart home devices, it is recommended, to develop and operate a program to certify new home as "Smart Energy Home". This certification will provide an affirmation that the home is compatible for participation in Demand Response program.

- **Incentives for real estate developers**: Installation of minimum set of smart home devices (defined under functionality) as a mandate of ENS, may lead to incurring of additional capital investment by real estate developer and not all consumer may be willing to pay additional amount. Therefore, to promote use of smart home devices, it is recommended to develop an appropriate scheme to provide incentives to real estate developer for installing smart home devices as default in new homes. Incentive may include tax credits, discounts on certain fee etc.

Demand Response

- **Amendment of existing DSM regulations:** Existing DSM regulation do not mandate development of DR programs or considers DR as source of energy. Therefore, to promote use of smart home devices, it is recommended to make amendments in DSM regulations to include appropriate provision for DR programs (as a responsibility of utility) and incentives (for participation by consumers). Availability of attractive demand response program will help in creating a demand-pull from residential consumers.

- **Support for development of standard DR program to utilities:** Demand response program are currently in pilot stage in India and in most of the cases the pilot implementation conducted through manual interventions. Therefore, to build capacity of utilities for developing appropriate demand response program (both auto and manual), it is recommended to develop a scheme for provide technical assistance utilities for this purpose. Detailed scheme can be developed based on detailed need assessment study for sample utilities.

- **Scheme for certification and empanelment of DR aggregator:** The demand response potential of individual house is limited in comparison to the requirement of a utility and it may be difficult for utility to communicate and manage DR program with numerous individual consumers on real time basis. In this scenario, an existing entity such as data, DTH, or any other service provider may aggregate thousands of consumers together and provide a higher volume of DR to utility. To catalyze development of aggregators, it is recommended to develop a scheme for certification and empanelment of entities that may be eligible to play role of aggregators.

- **Integration of DR and distributed energy source with electricity exchange:** With penetration of smart home devices, solar roof top and electric vehicles in medium term, homes may become prosumers (i.e. Individual homes that consume and produce electricity). Going forward, with increase in share of renewable energy in electricity generation, prosumers may become an important supplier for grid. Considering this, Federal Electricity Regulatory Commission (FERC) in its recent order[23] has opened wholesale electricity markets to distributed energy sources (such as electric vehicles, intermittent generation, demand response, energy efficiency, thermal storage etc.). With penetration of smart home devices and distributed energy sources, numerous homes in India are expected to become prosumers in future, therefore, it is recommended to conduct a feasibility study of integration of Demand Response and distributed energy sources with electricity exchange. Based on results, appropriate guidelines and policies should be developed for integration of DR and other distributed energy sources with electricity exchanges.

[23] https://www.ferc.gov/news-events/news/ferc-opens-wholesale-markets-distributed-resources-landmark-action-breaks-down

5.3 Implementation road map

Based on the expected timeline of implementation the recommendations can be classified in short term (1 – 3 years), medium term (4 – 6 years) and long term (6 – 10 years). Brief about each of term, list of interventions and its rationale is provided in subsequent sections.

5.3.1 Short term – Recommendation type: enablers

Interventions expected to be implemented in short term are the prerequisite for establishment of a decent size smart home market in India, therefore interventions of short term may be termed as the enablers of smart home market. List of interventions included in short terms are provided in figure below:

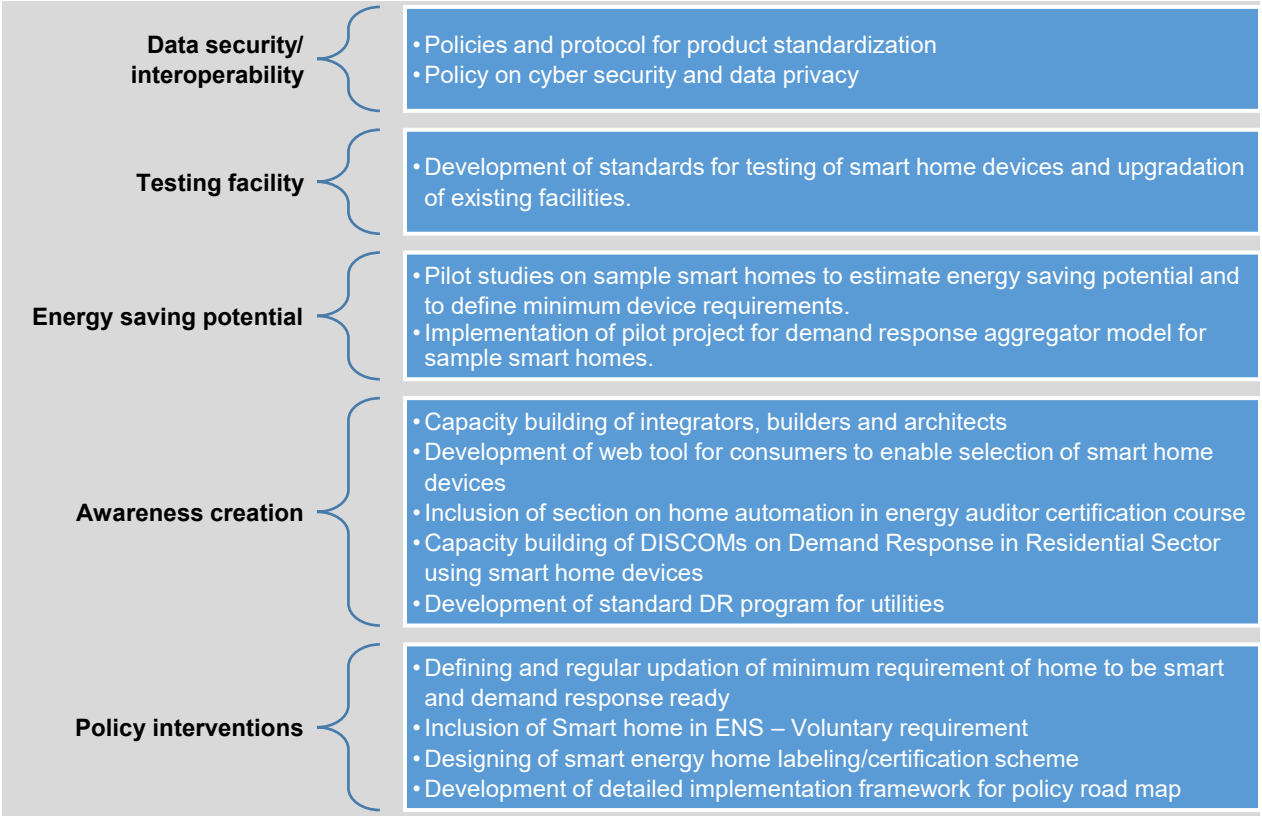


Figure 35 Short term recommendations of national road map

Details about the recommendation of short term such as objective, expected outcome and concerned agency is provided in table below:

Table 20 Short term recommendations of national road map

S. No	Intervention type	Intervention	Objective	Expected outcome	Concerned agency
1	Research	Undertaking pilot studies	To Create baseline, to estimate energy savings and DR potential with feedback and basic or advanced automation	Baseline, energy saving potential, consumer preference and response	BEE, Ministry of Power
2	Policy intervention	Inclusion of smart home requirement in ENS - Voluntary requirement	To include requirements of SHEMS in ENS as voluntary requirement	SHEMS becomes voluntary requirement of ENS	BEE, Ministry of Power

S. No	Intervention type	Intervention	Objective	Expected outcome	Concerned agency
3	Policy intervention	Defining minimum requirement of home to be smart and demand response ready	To list smart home devices to be installed to make home demand response ready	Minimum requirement - List of smart home devices and technical specification. The list can be updated annually/bi-annually	BEE, Ministry of Power
4	Policy intervention	Development of policies and protocol for product standardization	To develop protocol and policies for product standardization to promote common ecosystem	Policy on smart home device communication and software standardization	Bureau of Indian Standards and Ministry of Communication
5	Policy intervention	Development of data privacy and cyber security policy	To define minimum security requirement for data privacy and cyber security	Policy on data privacy and cyber security	Ministry of Electronics and Information Technology
6	Infrastructure	Defining standards for testing of smart home devices and upgradation of existing facilities	To provide support for establishment of basic testing provisions of smart home devices at existing facility	Facility for performance and compliance testing of smart home device	Bureau of Indian Standards and Ministry of Communication
7	Awareness	Capacity building of integrators, builders and architects	To create awareness among builders and architects to promote use of smart home devices in new homes	Improved awareness among bulk user	BEE, Ministry of Power
8	Awareness	Development of tool for users for enable selection of smart home devices	To develop an interactive tool for users to support selection of smart home devices and for estimation of energy savings	Improved consumer awareness and increase in smart home devices	BEE, Ministry of Power
9	Awareness	Inclusion of section on home automation in energy auditor certification course	To include concept and technical aspects of automation technologies in Energy Auditor certification course	Awareness among energy professional about home automation technologies	BEE, Ministry of Power
10	Awareness	Capacity Building of DISCOM on demand response and development of standard DR program	To improve awareness about demand response among officials of DISCOM through training, implementation of pilot projects and development of standard DR program	Improved awareness, estimation of DR potential and roll out of standard DR program	BEE, Ministry of Power
11	Demonstration	Demonstration project for demand aggregator model for demand response	To demonstrate demand aggregation service	Feasibility and benefits of DR aggregation	BEE, Ministry of Power

5.3.2 Medium term – Recommendations to increase demand

It is expected that the enabling system which includes policy on data privacy (and cyber security), policy/guidelines on product standardization, minimum requirements of smart home, SHEMS in ENS, testing facility and basic awareness among stakeholders, will be achieved in Indian Smart Home Market by end of short term.

In medium term, for further increase in penetration of smart home devices, the interventions will focus on increasing the demand of smart home devices by using both demand “push and pull” approach. It is expected that there will be several interventions in smart home domain that will targets different stakeholders to create:

- Demand push by designing appropriate mandates / guidelines for consumers,
- Demand pull by designing schemes for reducing overall cost of ownership for smart devices,
- Demand Response incentives as enablers (through platform and system for DR transactions);
- Enabling environment and framework

List of interventions included in medium terms are provided in figure below

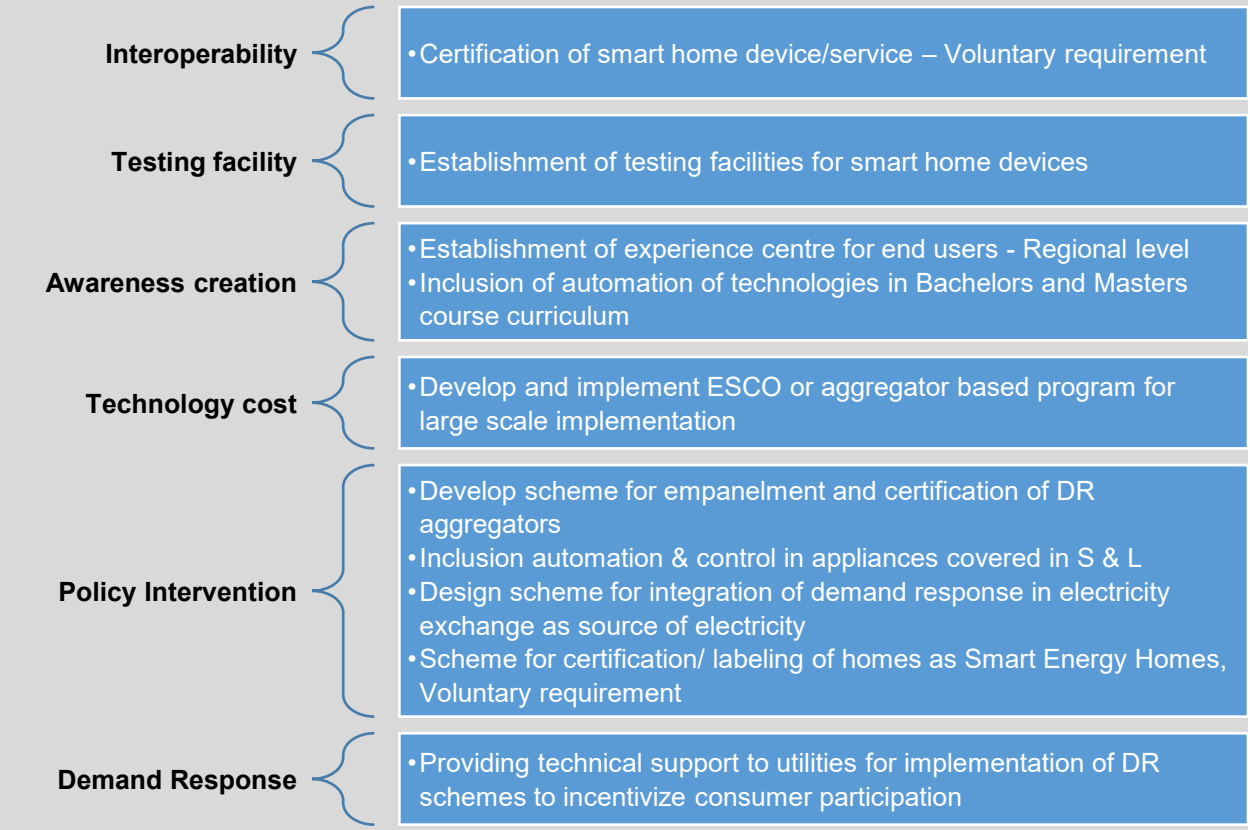


Figure 36 Medium term recommendations of national road map

Details about the recommendation of medium term such as objective, expected outcome and concerned agency is provided in table below:

Table 21 Medium term recommendations of national road map

Sr. No	Intervention type	Intervention	Objective	Expected outcome	Concerned agency
1	Awareness	Establishment of experience Centre for end users - Regional level	To establish user experience Centre for consumer awareness	Improved consumer awareness and increase in smart home devices	BEE, Ministry of Power
2	Technology cost	Develop and implement ESCO based program for large replication based	To design and implement ESCO projects for large scale replication of basic smart package to make	Large scale implementation of basic smart home package	BEE, Ministry of Power

Sr. No	Intervention type	Intervention	Objective	Expected outcome	Concerned agency
		on product or service model	homes demand response ready	product/service through ESCO	
3	Awareness	Inclusion of automation of technologies in university course curriculum	To include concept and technical aspects of automation technologies in university course curriculum	Course of home automation	Ministry of Education
4	Interoperability	Certification of smart home device/service	To design certification scheme to ensure minimum functionality of smart home devices - Voluntary	Certification scheme	BEE, Ministry of Power
5	Policy intervention	Certification scheme for smart energy homes	To design certification scheme for new homes as smart energy homes Voluntary requirement	Certification scheme	BEE, Ministry of Power
6	Infrastructure	Establishment of testing facilities	To promote establishment of advanced testing facilities of smart home devices	Facility for performance and compliance testing of smart home device	BEE, Ministry of Power
7	Demand Response	Technical support for implementation of DR	To provide technical support to utilities for implementation of DR schemes to incentivize consumer participation	DR program implemented at DISCOMs	BEE, Ministry of Power
8	Policy intervention	Upgradation of S & L scheme to include appliance controlling	To include automation as control requirement in individual appliance S & L protocol	Upgraded S & L Protocol	BEE, Ministry of Power
9	Policy intervention	Registration of DR aggregator	To develop scheme for empanelment and certification of DR aggregators	List of empaneled DR aggregators	BEE, Ministry of Power
10	Policy intervention	Inclusion of Demand Response in electricity exchange	To design scheme for integration of demand response in electricity exchange as a source of electricity	Inclusion DR as source of electricity on electricity exchange	BEE, Ministry of Power

5.3.3 Long term – Recommendations for large scale replication and for sustainable growth

After implementation of interventions of medium term, it is expected that, the smart home market in India may have reached the growth / self-propelling stage with all requisite policies/guidelines and support scheme in place. To further consolidate this growth, it is proposed that in long term, some of the policies, such as certification of smart home device/services and labeling of new homes may be made mandatory.

Along with this, to ensure demand pull, utilities would require technical support for implementation of DR schemes. Implementation of such schemes will ensure availability of incentive for consumers in the form of DR benefits.

List of interventions included in long terms are provided in figure below:

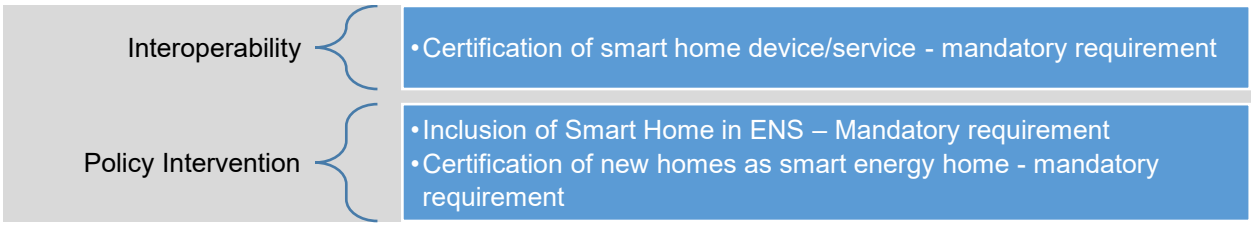


Figure 37 Long term recommendations of national road map

Details about the recommendation of long term such as objective, expected outcome and concerned agency is provided in table below:

Table 22 Long term recommendations of national road map

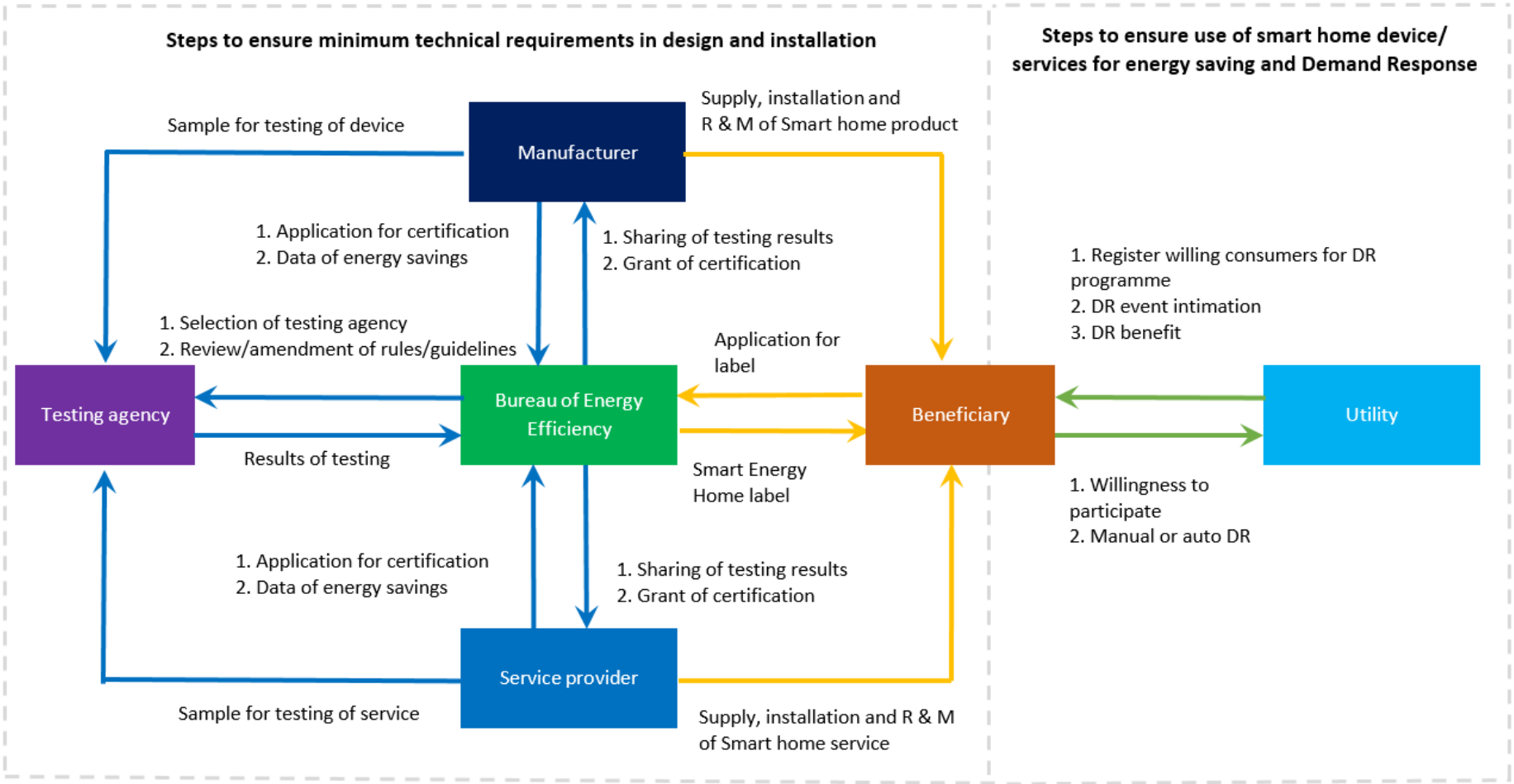
Sr. No	Intervention type	Intervention	Objective	Expected outcome	Concerned agency
1	Interoperability	Certification of smart home device/service	To design certification scheme to ensure minimum functionality of smart home devices – Mandatory requirement	Certification scheme	BEE, Ministry of Power
2	Policy intervention	Inclusion of smart home requirement in ENS - Mandatory requirement	To include minimum smart home devices requirement in ENS - Mandatory for new homes	Section on automation in ENS	BEE, Ministry of Power
3	Policy intervention	Certification of new and existing homes	To roll out certification scheme for new homes as smart energy homes – Mandatory requirement	Certification scheme	BEE, Ministry of Power

5.4 Implementation framework for certification system and labeling scheme

To promote use of smart home devices / services, certification may be required to serve following purposes:

- Standardisation of smart home devices (minimum technical requirements including energy performance)
- Standardisation for minimum number of smart devices in a dewelling for qualification as “smart home”

The flow of activities and the roles, expected of various stakeholders for the mentioned certification (of smart home device/service and smart dwelling) is provided in the schematic below:



Particular	Legend
Step for certification of Smart home product/service	
Step for labelling of a dwelling as Smart Energy Home	
Steps for demand response	

Purpose of certification:

Certification for smart home devices / services: To ensure interoperability and to ensure compliance of energy efficiency standards of SHEMS devices to minimize standby power consumption

Labeling of dwelling: To ensure utilization of smart options by providing benefits in utility bill through demand response program

Role and responsibilities of stakeholders:

Stakeholder	Details	Role and responsibilities
Bureau of Energy Efficiency	Regulator, administrator	**Towards testing agency** • Defining qualification criteria for testing agency • Selection of testing agency • Development of testing procedure and standards for testing agency **Towards manufacturer and service providers of SHEMS** • Defining minimum technical requirements and minimum energy performance standards for SHEMS products and services • Development of formats for data submission • Defining fee for certification • Processing of application for certification • Awarding of compliance certification to manufacturer and service providers **Towards Beneficiary** • Development data submission formats for beneficiary • Defining fee for Smart Energy Home certification • Awarding Smart Energy Home certification to beneficiary
Beneficiary	Builder or owner or aggregator (on behalf of owner)	• Submission of application to BEE for certification of dwelling as Smart Energy Home • Apply for participation in DR program of utility • Participate in demand response event in manual or auto mode
Manufacturer or service provider	Manufacturer of SHEMS device, service provider	• Design and manufacturer product or services in compliance of guidelines of BEE • Apply for certification of SHEMS product or services to BEE • Supply, installation and R & M of SHEMS devices/services at consumer end
Testing agency	NABL accredited laboratories	• Test the samples provided by manufacturers and service providers as per the standards and guidelines of BEE • Share the test results with BEE and the applicant
Utility		• Register certified Smart Energy Home for DR program • Convey DR event to registered consumers • Share the benefits or incentives for participation in DR event with consumer

5.5 Conclusion

The smart home technology space is evolving at an interesting pace and innovative business offerings (products as well as services) are being rolled out / experimented to make the technology acceptable and user friendly. Some of the positive development / updates of smart home space include:

- Global alliance and forums are being created to converge discussions on standardization and interoperability
- Energy saving potential of smart home which includes devices that provide measurement, monitoring, information displays, management, control, automation, zoning, occupancy systems, etc. is estimated as 27%[24]
- Availability of smart home technologies are making homes demand response (DR) ready, which may help utilities in developing and executing large scale DR program
- Installation of smart meters, which is being undertaken at large scale across the country, will provide much needed time of day (ToD) metering provision to residential sector and may provide a fresh push to demand of smart home products and services

In present scenario, evolution of smart home technology, development of attractive product / service offerings, access to funds and availability of high-speed internet and smart mobile computing is helping the market consolidate for smart home products / services which is essentially driven based on need of security and comfort. Implementation of recommendations, proposed through the national policy road map, may help in resolving the present barriers to adoption of smart home technologies in India. This in turn may catalyze large scale implementation of smart home technologies and may support in accruing benefits of energy efficiency and demand response in residential sector in India.

Indian market may follow the trends like other developed nations, where the smart home market is expected to grow by 10 folds[25] with implementation of some of the much-needed policies (listed in this chapter). Considering this factor and reduction in cost of technology with economies of scale, Indian smart home market size is expected to grow to about US$ 62.8 billion by the end of 2030 (with regular policy interventions by concerned departments) and the penetration level (with reference to total number of households in India by 2030) is exacted to reach 28%.

Considering the above-mentioned penetration at national level, energy saving potential by adoption of smart home devices is expected to be 94 billion units in 2030, which will be about 15% of electricity consumption of residential sector in 2030. On human resource and skill development front, smart home market is expected to add about 2.5 to 3 million new jobs by 2030. These jobs will be created with manufacturers, OEMs, data and service providers, system integrators, architects, consultants and with other related stakeholders.

[24] Source: Intelligent Efficiency: Case study of barriers and solutions - Smart Homes, Connected Device Alliance, 4E's Electronic Devices and Networks Annex (EDNA), March 2018

[25] As per Intelligent Efficiency – Case study of barriers and solutions – smart homes report (Connected device alliance report, the smart home device penetration in US was 5% in 2015. As per Statista estimate the US smart home device penetration in expected to reach about 51.4% by 2024. As of now US have policies on data privacy, IoT device standardization and Energy star labeling for smart home energy management system (SHEMS)

Annexure – 1 Techno – commercial analysis of smart home devices and retrofits

1. Smart Geyser

Features:

Figure 38 Smart Geyser

Ease of control: Control the geyser from anywhere using mobile app

- **Optimisation of set temperature**: Based on AI based learning the device develops understanding about user preference and adjusts the set point of hot water output accordingly.
- **Notification**: The smart device provides notification when:
    - Hot water is available
    - Amount of hot water available and temperature of hot water, which helps user to take call about whether to switch on the geyser or not.
    - Alert about running for defined time in the day, to avoid idle running
    - Alert about fault or service requirement.
- **Scheduling:** The user can schedule the geyser to operating in off peak duration, this will help in availing in time of day tariff benefits on electricity bill.

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a conventional geyser is comapred with smart geyser. For baseline, a conventional geyser of 25 litre capacity and 2 kW power rating was considered. The conventional geyser does not include features such as setting up the water outlet temperature, remote oepration, scheduling etc. Annual Operating hours were considered as 600 hours/ annum (3 hours per day for 200 days).

b. Energy and cost saving provisions of smart geyser

For estimation of energy savings from smart geyser, following provisons were considered in calculation

- The set temperature in smart geyser can be controlled manully by consumer or using AI based program which takes in consideration ambient weather, user preference and availability of water in hot water storage tank. For calcualtion purpose the set point is considered at 43 ^{0}C, the upper limit of recommendation by Covenant Health chain of hospitals (and vetted by national health bodies of Canada). For estimation of saving due to temperature control, it is assumed that during a shower, user drains about 20% water to attain the optimum temperature.
- The idle running of conventional geyser is considered as 12 hours per week. With smart geyser this can be elimatated through mobile app alert.
- Time of day benefit or the discount on tariff for off peak operation, available with scheduling option is considered as 20%

Detailed calculation of techno commercial analysis of smart geyser is provided in table below:

Table 23 Techno Commercial Analysis of Smart Geyser

S. No	Particular	Unit	Value
	Baseline		
1	No. of Geyser	No.	1

S. No	Particular	Unit	Value
2	Capacity	Liters	25
3	Power rating (3 star geyser)	kW	2
4	Average operating hours per day	hours	3
5	Standby losses[26]	kWh/24hour at 45 ^{0}C	0.618
6	Temperature upto which water is heated	Deg C	60
7	Average water inlet temperature	Deg C	20
8	Number of days per year	days	200
9	Annual operating hours	hours	600
10	Annual electricity consumption	kWh/year	946
11	Tariff of electricity	Rs. / kWh	6
12	Annual electricity cost	Rs. / year	5674
	Proposed solution - temperature control, scheduling and remote operation		
13	Optimization of set temperature (43 ^{0}C)[27]	Deg C	43
14	Avoiding idle running (assumption: the geyser left running once a week for 12 hours)	Nos.	29
15	Operating geyser in off peak period - discount on tariff	%	20%
	Energy Savings		
16	Annual energy savings from temperature control, (20% of hot water gets wasted in shower by user in an attempt reach the required temperature)	kWh/year	79
17	Annual energy savings by prevention of idle running	kWh/year	9
18	Total electricity savings	kWh/year	88
19	Cost savings due to reduction in electricity consumption	Rs. / year	527
20	Cost savings in electricity bill due to off peak operation (75% of the time)	Rs. / year	846
21	Total cost savings	Rs. / year	1374
	Investment		
22	Differential cost of smart geyser with features[28] such as temperature control, scheduling and remote operation	Rs.	4650
	Payback		
23	Simple Payback period	Year	3.4

Based on above, it is estimated that replacement of convetional geyser with smart geyser will lead to energy savings of about 9.3% over the baseline situation. The simple payback for this investment is estimated to be 3.4 years.

In case the annual operating hours of geyser, in above case, considered as 6000[29] hours, the percentage energy savings of about 16.1% over the baseline situation and simple payback for this investment would be 1.6 Years.

[26] Source: BEE Standard and Labeling: Geyser Notification, standby losses of 5 star geyser of 25 liter
[27] Source: The Covenant Health chain of hospitals has published a policy vetted by national health bodies of Canada that recommends water temperature between 38°C and 43°C would be safe for bathing.
[28] Difference of existing model with and without mentioned features
[29] Source: BEE report on Impact of Energy Efficiency for the year 2018-19

2. Smart Plug enabled geyser

Features:

- **Ease of control**: Control the geyser from anywhere using mobile app
- **Scheduling:** The user can schedule the geyser to operating in off peak duration, this will help in availing in time of day tariff benefits on electricity bill.

Figure 39 Smart Plug

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a conventional geyser with
and without a smart plug is comapred. For baseline, a conventional geyser of 25 litre capacity and 2 kW power rating was considered. The conventional geyser does not include features such as ease of control, scheduling etc. Annual Operating hours were considered as 600 hours/ annum (3 hours per day for 200 days).

b. Energy and cost saving provisions of smart plug enabled geyser

For estimation of energy savings from smart plug, following provisons were considered in calculation

- The idle running of geyser without smart plug is considered as 12 hours per week. With smart plug geyser this can be elimatated through mobile app alert.
- Time of day benefit or the discount on tariff for off peak operation, available with scheduling option is considered as 20%

Detailed calculation of techno commercial analysis of smart plug enabled geyser is provided in table below:

Table 24 Techno Commercial Analysis of Smart plug enabled Geyser

S. No	Particular	Unit	Value
	Baseline		
1	No. of Geyser	No.	1
2	Capacity	Liters	25
3	Power rating (5-star geyser)	kW	2
4	Average operating hours per day	hours	3
5	Standby losses	kWh/24hour at 45 Deg C	0.618
6	Temperature upto which water is heated	Deg C	60
7	Average water inlet temperature	Deg C	20
8	Number of days per year	days	200
9	Annual operating hours	hours	600
10	Annual electricity consumption	kWh/year	946
11	Tariff of electricity	Rs./kWh	6
12	Annual electricity cost	Rs./year	5674
	Proposed solution - scheduling and remote operation		
13	Avoiding idle running (assumption: the geyser left running once a week for 12 hours)	Nos.	29
14	Operating geyser in off peak period - discount on tariff	%	20%
	Energy Savings		
15	Annual energy savings by prevention of idle running	kWh/year	9
16	Cost savings due to reduction in electricity consumption	Rs. / year	53
17	Cost savings in electricity bill due to off peak operation (75% of the time)	Rs. / year	846

S. No	Particular	Unit	Value
18	Total cost savings	Rs. / year	899
	Investment		
19	Cost of smart plug that provide scheduling and remote operation	Rs.	500
	Payback		
20	Simple Payback period	Year	0.6

Based on above, it is estimated that installation of smart plug on convetional geyser will lead to percentage energy savings of about 1%[30] over the baseline situation. The simple payback for this investment is estimated to be 0.6 years. **In case the annual operating hours of geyser, in above case, considered as 6000 hours[31], the percentage energy savings of about 8.5% over the baseline situation and simple payback for this investment would be less than 3 month.**

[30] The estimated energy savings are similar to the findings of smart plug pilot mentioned in NEEP report – Opportunities for Home Energy Management System (HEMS) in advancing residential Energy Efficiency Programs

[31] Source: BEE report on Impact of Energy Efficiency for the year 2018-19

Upcoming technologies in water heating

a. *Heat pump water heater*

In geyser space, the upcoming technology is heat pump based geyser, which are expected to far more efficient than heater element based geyser. Schemetics of heat pump based geyser and working flow is provided in figure below:

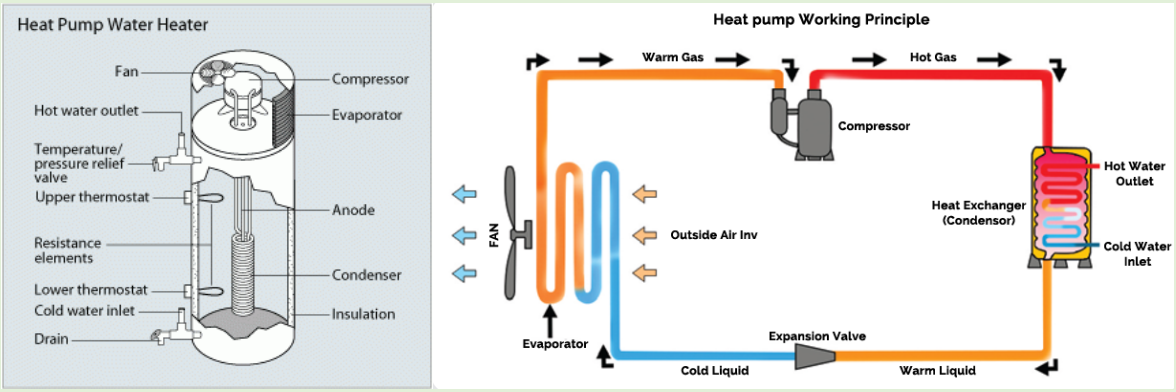


Figure 40 Heat pump based geyser

Figure 41 Working principal - Heat pump based geyser

Heat pump water heater transfers heat by circulating refrigerant through a cycle of evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant with low temperature and pressure absorbs heat from its surrounding air and in the second coil, the refrigerant with high temperature and pressure transfers heat to water.

b. Tri-generation for buildings

A tri-generation system uses only one source of primary energy, while providing power, heating and cooling simultaneously. This primary source can be represented by either fossil fuels or some appropriate renewable energy sources (biomass, biogas, solar energy, etc.). Schematic of tri-generation system is provided in figure below:

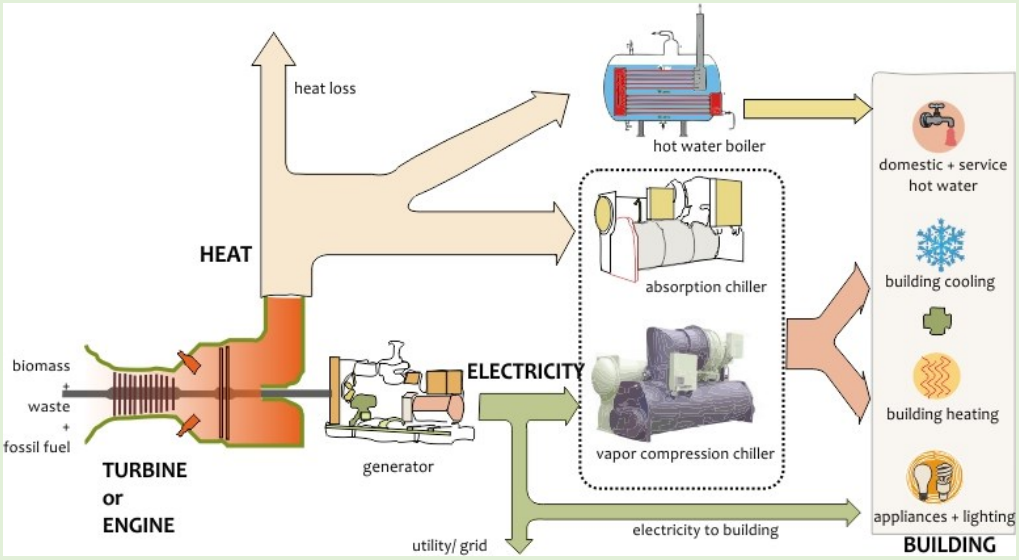


Figure 42 Tri-generation system for buildings

3. Smart AC

Features:

- **Ease of control**: Control the AC from anywhere using mobile app
- **Optimisation of set temperature**: Based on AI based learning the AC develops understanding about ambient conditions, user preference and adjusts the set point for chilled air outlet or the operation mode accordingly.
- **Notification**: The smart device provides notification:
    - Alert about running for defined time in the day, to avoid idle running
    - Alert about fault or service requirement.

Figure 43 Smart AC

- **Scheduling:** AC can be scheduled to operate in specific mode (for instance in night) as per user requirement

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a conventional 3 star AC is comapred with smart AC. For baseline, a conventional AC of 1.5 TR capacity was considered. The conventional AC does not include features such as ease of control, scheduling, AI based setting up of temperature and automatic mode selection etc. Annual Operating hours were considered as 1600 hours[32].

b. Energy and cost saving provisions of smart AC

For estimation of energy savings from smart AC, following provisons were considered in calculation

- The set temperature and operating mode in smart AC can be controlled manully by consumer or using AI based program which takes in consideration ambient weather and user preference. For calcualtion purpose the set point is considered at 24 ^{0}C, the default value mandated by BEE in new air conditioners. With AC based controlling of temperature and mode, the set point may be increased upto 26 ^{0}C.

Figure 44 Smart AC – example of AI based controlling

The idle running of conventional AC is considered as 160 hours per year. With smart AC, there are two options:

- User will get alert through mobile app.
- AC will automatically run in specific mode to reduce energy consumption. One of the example taken from manufacturer website is provided in adjacent figure.

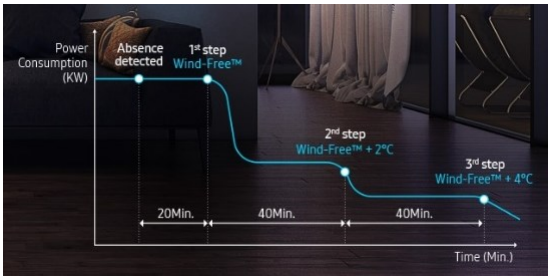


Figure 45 Smart AC – example of response to idle running

[32] Source: BEE S & L: RAC notification

Detailed calculation of techno commercial analysis of smart AC is provided in table below:

Table 25 Techno Commercial Analysis of Smart AC

S. No	Particular	Unit	Value
	Baseline		
1	No. of AC	No.	1
2	Capacity	TR	1.5
3	Power rating (3 Star AC)	ISEER	3.6
4	Annual operating hours	hours	1,600
5	Annual electricity consumption	kWh/year	2,344
6	Tariff of electricity	Rs./kWh	6
7	Annual electricity cost	Rs./year	14,065
	Proposed solution – Smart AC		
8	Average set temperature without AI based control	Deg C	24
9	Average set point with AI based control	Deg C	26
10	Avoiding idle running of AC with motion sensor - shifting to standby mode (Assumption: 10% of the time)	hours	160
	Energy Savings		
11	Annual energy savings from increase in set temperature	kWh/year	211
12	Annual energy savings by prevention of idle running, (estimated based on manufacturer claim)	kWh/year	181
13	Total electricity savings	kWh/year	391
14	Total cost savings	Rs. /year	2,349
	Investment		
15	Differential cost of Smart AC (over conventional) or cost of smart thermostat	Rs.	9,000
	Payback		
16	Simple Payback period	Year	3.8

Based on above, it is estimated that replacement of convetional AC with smart AC or retroftiing of smart thermostat will lead to energy savings of about 16.7%[33] over the baseline situation. The simple payback for this investment is estimated to be 3.8 years.

4. IR Blaster enabled AC

Features:

Figure 46 IR Blaster

- **Ease of control**: Control the AC from anywhere using mobile app
- **Scheduling:** AC can be scheduled to operate in specific mode (for instance in night) as per user requirement
- **Sequencing:** User can program switching of multiple devices including AC with single command over app or voice-based hub. For instance, while leaving for office, single command will switch off all devices linked with IR blaster.
- **Trigger:** User can program switching of multiple devices including AC as per schedule. For instance, switch off all devices linked with IR blaster at 10:00 am.

[33] The estimated energy savings are similar to the findings of smart thermostat pilot mentioned in NEEP report – Opportunities for Home Energy Management System (HEMS) in advancing residential Energy Efficiency Programs

- **Geofencing:** User can program switching of multiple devices based on mobile location. For instance, once user more than 100 meters from home, all devices linked with IR will switch off.

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a conventional 3 star AC is comapred with similar AC coupled with IR Blaster. For baseline, a conventional AC of 1.5 TR capacity was considered. The conventional AC does not include features such as anywhere oepration, scheduling, sequening, go fencing and trigger option etc. Annual Operating hours were considered as 1600 hours[34].

b. Energy and cost saving provisions of IR blaster enabled AC

For estimation of energy savings from IR blaster enabled AC, the idle running of conventional AC is considered as 160 hours per year. With IR Blaster, using features mentioned above like scheduling, sequencing, trigger and geo fencing the idle running of AC and other appliances can be prevented.

Detailed calculation of techno commercial analysis of IR Blaster enabled AC is provided in table below:

Table 26 Techno Commercial Analysis of IR blaster enabled AC

S. No	Particular	Unit	Value
	Baseline		
1	No. of AC	No.	1
2	Capacity	TR	1.5
3	Power rating (5 Star AC)	ISEER	3.6
4	Annual operating hours*	hours	1,600
5	Annual electricity consumption	kWh/year	2,344
6	Tariff of electricity	Rs. / kWh	6
7	Annual electricity cost	Rs. / year	14,065
	Proposed solution - Installation of IR blaster		
8	Idle running hours (is considered as 10% of the total operation time) - idle running of AC can be avoided with IR blaster using remote operation, scheduling, app based personal routine program, trigger and geo fencing	hours	160
	Energy Savings		
9	Annual energy savings by prevention of idle running	kWh/year	211
10	Annual electricity consumption by IR blaster	kWh/year	4
11	Net electricity savings	kWh/year	207
12	Total cost savings	Rs. / year	1,245
	Investment		
13	Cost of IR Blaster	Rs.	1,500
	Payback		
14	Simple Payback period	Year	1.2

Based on above, it is estimated that instalaltion of IR blaster on conventional AC will lead to energy savings of about 9% over the baseline situation. The simple payback for this investment is estimated to be 1.2 years.

[34] Source: BEE S & L: RAC notification

District cooling

A district cooling system[#] (DCS) distributes cooling capacity in the form of chilled water or other medium from a central source to multiple buildings through a network of underground pipes for use in space and process cooling. Individual user purchases chilled water for their building from the district cooling system operator and do not need to install their own chiller plants. For this system, a central chiller plant, a pump house and a distribution pipeline network are required.

The DCS is an energy-efficient air-conditioning system as it consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water-cooled air-conditioning systems using cooling towers respectively. In some countries that have substantial heating demand, the plant can also be designed to supply hot water to form a District Heating and Cooling System (DHCS). A typical DCS comprises the following components:

- Central Chiller Plant - generate chilled water for cooling purposes.
- Distribution Network - distribute chilled water to buildings
- User Station - interface with buildings' own air-conditioning circuits

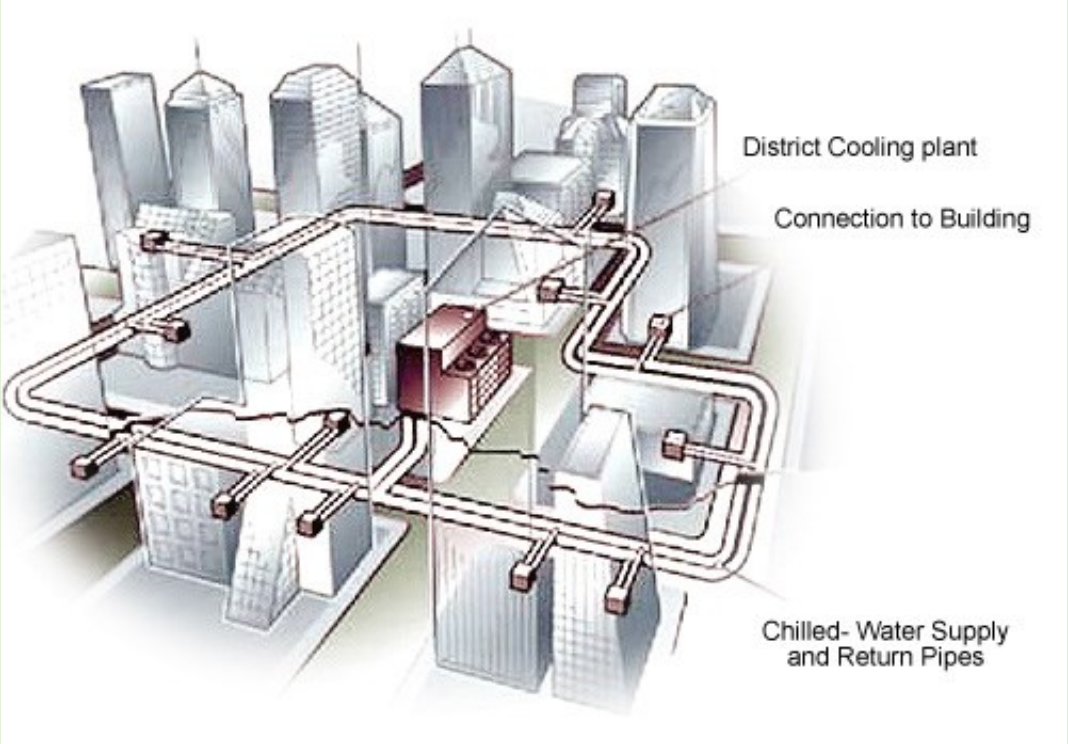


Figure 47 District Cooling System

Source: Electrical and Mechanical Services Department, The government of the Hong Kong Special Administrative Region, https://www.emsd.gov.hk/energyland/en/building/district_cooling_sys/dcs.html

5. Smart Washing Machine

Features:

Figure 48 Smart washing machine

- **Ease of control**: Control the washing machine from anywhere using mobile app
- **Optimisation of set washing mode**: Based on sensors, AI based learning and user preference the washing machine develops understanding about weight of load, type of cloth, dirt level etc. and washing mode accordingly.
- **Notification**: The smart device provides alert about fault or service requirement.
- **Scheduling:** Washing machine can be scheduled to operate at specific time, especially in off peak time to take benefit of utility incentives.
- **Regular update:** The smart washing machine can update its database of washing programme through over the air (OTA) updates provided by the supplier, similar to mobile OS update, to improve the performance.

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a conventional washing machine is comapred with smart washing machine. For baseline, a conventional front loading 8 kg capacity was considered. The conventional washing machine does not include features such as ease of control, scheduling and sensor, user or AI washing mode selection etc. Annual Operating hours were considered as 730 hours.

b. Energy and cost saving provisions of smart washing machine

For estimation of energy savings from smart washing machine, following provisons were considered in calculation

- The washing mode of smart washing machine can be controlled manully by consumer or using AI based program which takes in consideration parameters like weight of load, type of cloth, dirt level etc. Along with reduction in cycle time, with smart washing machine, the energy consumption also reduces due to change in factors like the amount of water, detergent and RPM and operating pattern of drum motor. Percentage energy saving considered for smart washing machine are provided below:

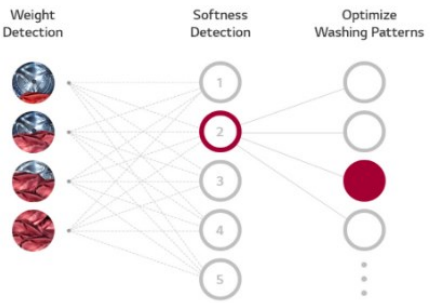


Figure 49 Smart washing - AI based washing mode selection

  - Optimization of operation based on weight of laundary, percentage energy savings at 2/3 load – 16.4%[35]
  - Maintenance alert to clean lint trap/ vents regularly, percentage energy savings – 0.92%[36]
  - Use of autosetting for dyer instead of fixed time, percentage energy savings – 1.38%[37]

[35] Source: South California Edison report on demand response potential of residential appliance - Cloth Washer
[36] Source: NEEP report – Opportunities for Home Energy Management System (HEMS) in advancing residential Energy Efficiency Programs
[37] Source: NEEP report – Opportunities for Home Energy Management System (HEMS) in advancing residential Energy Efficiency Programs

- With help of scheduling option, the smart washing machine can be operated in off peak time. Benefit of off peak operation is considered as 20% discount over present tariff.

Detailed calculation of techno commercial analysis of smart washing machine is provided in table below:

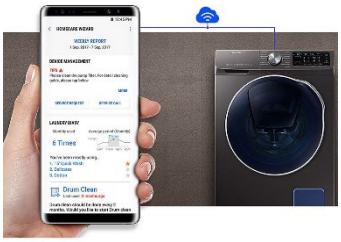


Figure 50 Smart washing machine – scheduling option

Table 27 Techno Commercial Analysis of Smart Washing Machine

S. No	Particular	Unit	Value
	Baseline		
1	No. of Washing Machine	No.	1
2	Capacity	Kg	8
3	Type		Front loading wash cum dryer
4	Power rating	kW	2.25
5	Average operating hours per day	hours	2
6	Number of days per year	days	365
7	Annual operating hours	hours	730
8	Annual electricity consumption*	kWh/year	526
9	Tariff of electricity	Rs./kWh	6
10	Annual electricity cost	Rs./year	3154
	Proposed solution - Optimization of cycle time and scheduling		
11	Optimization of operation based on weight of laundry, percentage energy savings at 2/3 load#	%	16.4%
12	Maintenance alert to clean lint trap/ vents regularly, percentage energy savings	%	0.9%
13	Use of auto setting for dyer instead of fixed time, percentage energy savings	%	1.4%
14	Shifting of operation during off peak time, percentage discount on tariff	%	20%
	Energy Savings		
15	Annual energy savings from reduction in cycle time	kWh/year	98
16	Cost savings due to reduction in electricity consumption	Rs. / year	590
17	Cost savings in electricity bill due to off peak operation	Rs. / year	631
18	Total cost savings	Rs. / year	1221
	Investment		
19	Cost of additional features in smart washing machine that provide optimized cycle time, scheduling and remote operation	Rs.	4714
	Payback		
20	Simple Payback period	Year	3.9

Based on above, it is estimated that replacement of conventional washing machine with smart washing machine will lead to energy savings of about 18.7% over the baseline situation. The simple payback for this investment is estimated to be 3.9 years.

6. Smart plug enabled washing machine

Figure 51 Smart plug enabled washing machine

Features:

- **Ease of control**: Control the washing machine from anywhere using mobile app
- **Scheduling:** Washing machine can be scheduled to operate at specific time, especially in off peak time to take benefit of utility incentives.

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a conventional washing machine is comapred with smart washing machine. For baseline, a conventional front loading 8 kg capacity was considered. The conventional washing machine does not include features such as ease of control, scheduling and sensor, user or AI washing mode selection etc. Annual Operating hours were considered as 730 hours.

b. Energy and cost saving provisions of smart plug enabled washing machine

For estimation of energy savings from smart plug enabled washing machine, following provisons were considered in calculation

- With help of scheduling option, the smart washing machine can be operated in off peak time. Benefit of off peak operation is considered as 20% discount over present tariff.

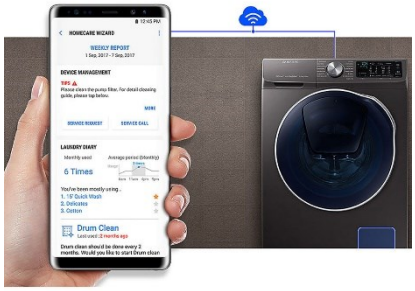


Figure 52 Smart plug enabled washing machine – scheduling option

Detailed calculation of techno commercial analysis of smart plug enabled washing machine is provided in table below:

Table 28 Techno Commercial Analysis of Smart plug enabled Washing Machine

S. No	Particular	Unit	Value
	Baseline		
1	No. of Washing Machine	No.	1
2	Capacity	Kg	8
3	Type		Front loading wash cum dryer
4	Power rating	kW	2.25
5	Average operating hours per day	hours	2
6	Number of days per year	days	365
7	Annual operating hours	hours	730
8	Annual electricity consumption*	kWh/year	526
9	Tariff of electricity	Rs. / kWh	6
10	Annual electricity cost	Rs. / year	3153.6
	Proposed solution - Optimization of scheduling		
11	Shifting of operation during off peak time, percentage discount on tariff	%	20%
	Energy Savings		
12	Cost savings in electricity bill due to off peak operation	Rs. / year	631
	Investment		
14	Cost of smart plug scheduling and remote operation	Rs.	500
	Payback		

S. No	Particular	Unit	Value
15	Simple Payback period	Year	0.8

Based on above, it is estimated that installation of smart plug on conventional washing machine will lead to cost savings of about 20% over the baseline situation. The simple payback for this investment is estimated to be 0.8 years

7. Occupancy sensor for light and exhaust fan

Figure 53 Occupancy Sensor

Features:

- **Avoids idle running**: The occupancy sensor will switch off the light and exhaust fan in case on non-occupancy

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a LED bulb (9 W) and exhaust fan (40 W) with and without an occupancy sensor is comapred. Annual Operating hours were considered as 1354 hours/ annum (3 hours per day for 365 days and idle running of 12 hours per week).

b. Energy and cost saving provisions of occupancy sensor

For estimation of energy savings from occupancy senor, following provisons were considered in calculation

- The idle running of LED bulb and exhaust fan without occupancy sensor is considered as 12 hours per week. With occupancy sensor installed in bathroom, the idle running of LEB bulb and exhaust fan can be eliminated

Detailed calculation of techno commercial analysis of occupancy sensor is provided in table below:

Table 29 Techno - commercial analysis of occupancy sensor

S. No	Particular	Unit	Value
	Baseline		
1	No. of lights in Bathroom	No.	1
2	Power rating of LED bulb	Watt	9
3	No. of exhaust fans	No.	1
4	Power rating of exhaust fan	Watt	40
5	Average operating hours per day	hours	2
6	Number of days per year	days	365
7	Annual operating hours (2 hours per day and idle running for 12 hours a week)	hours	1354
8	Annual electricity consumption	kWh/year	66
9	Tariff of electricity	Rs. / kWh	6
10	Annual electricity cost	Rs. / year	398
	Proposed solution - Install occupancy sensor		
11	Avoiding idle running (assumption: the light and exhaust left running once a week for 12 hours)	hours	624
	Energy Savings		
12	Annual energy savings by installation of occupancy sensor	kWh/year	31
13	Annual cost savings	Rs. / year	184
	Investment		
14	Cost of occupancy sensor	Rs.	500
	Payback		

S. No	Particular	Unit	Value
15	Simple Payback period	Year	2.7

Based on above, it is estimated that installation of occupancy sensor will lead to energy savings of about 50% over the baseline situation. The simple payback for this investment is estimated to be 2.7 years

8. Smart Lighting

Features:

- **Dimming option**: Option of dimming the luminous intensity based on the task at hand.
- **Ease of control**: Control the lighting from anywhere using mobile app. This will prevent idle running
- **Scheduling**: Using mobile app light can be scheduled to operate a fixed schedule at mentioned luminous intensity

Figure 54 Smart lighting

Techno – commercial analysis

a. Baseline

For techno – commercial analysis a LED tube light (20 W) is compared with smart LED tube light. Annual Operating hours were considered as 2920 hours/ annum (8 hours per day for 365 days and idle running of 12 hours per week).

b. Energy and cost saving with smart lighting

For estimation of energy savings from smart lighting, following provisons were considered in calculation

- The idle running of LED tubelight is considered as 12 hours per week. With app based control and alert option this can be eliminated.
- Possibility of dimming the light to 50% illumination level for 4 hours per day.

Detailed calculation of techno commercial analysis of smart lighting is provided in table below:

Table 30 Techno - commercial analysis of smart lighting

S. No	Particular	Unit	Value
	Baseline		
1	No. of lighting fixture	No.	1
2	Wattage of individual fixture	Watt	22
3	Average operating hours per day	hours	8
4	Number of days per year	days	365
5	Annual operating hours (8 hours a day and idle running of 12 hours per week)	hours	3544
6	Annual electricity consumption	kWh/year	78
7	Tariff of electricity	Rs. / kWh	6
8	Annual electricity cost	Rs. / year	468
	Proposed solution - light with dimming, scheduling and remote operation feature		
9	Duration for dimming of light upto 50% per day (about 4 hours per day based on task)	hours	4
10	Duration for which idle running prevented per year with option of remote operation and app-based alert	hours	624
11	Annual energy consumption in proposed situation	kWh/year	46
	Energy Savings		
12	Annual Energy Savings by scheduled dimming and prevention of idle running	kWh/year	31
13	Annual cost savings	Rs. / year	187

S. No	Particular	Unit	Value
	Investment		
14	Cost of smart lighting with dimming, scheduling and operate from anywhere option	Rs.	566
	Payback		
15	Simple Payback period	Year	3.0

Based on above, it is estimated that replacement of existing LED tube light with smart LED tube light will lead to energy savings of about 40% over the baseline situation. The simple payback for this investment is estimated to be 3 years.

9. Energy Monitoring

Features:

- **Electricity consumption and generation monitoring**: Provides daily, weekly or monthly electricity consumption and generation report.
- **Energy saving tips**: Provides electricity saving tips based on analysis of electricity consumption pattern.

Figure 55 Energy monitoring system

Techno – commercial analysis

a. Baseline

For techno – commercial analysis, 3 BHK house is considered for baseline. Annual electricity consumption of 3 BHK is estimated as 3195 kWh per year using design builder tool.

b. Energy and cost saving with energy monitoring

For estimation of energy savings from energy monitoring, following provisons were considered in calculation

- Energy saving potential of energy monitoring system is considered as 12%[38] based on reviewed of a number of pilot studies done across the globe on energy monitoring system, where users are provided with energy consumption details and energy saving tips.

Detailed calculation of techno commercial analysis of energy monitoring system is provided in table below:

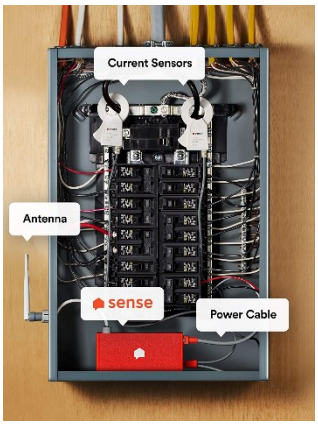


Figure 56 Energy monitoring system - Hardware installation

Table 31 Techno - commercial analysis of energy monitoring system

S. No	Particular	Unit	Value
	Baseline		
1	House size		3 BHK
2	Annual electricity consumption, estimated based on simulation done on design builder tool	kWh	3,195.0
3	Tariff of electricity	Rs. / kWh	6

[38] Source::Ehrhardt-Martinez, K., Donnelly, K. A. and Laitner, J.P. (2010): Advanced Me-tering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities. Report No. E105. American Council for an Energy-Efficient Economy, Washington, D.C.

S. No	Particular	Unit	Value
4	Annual electricity cost	Rs. / year	19,170
	Proposed solution - Installation of energy monitoring device		
5	Percentage energy savings*	%	12%
	Energy Savings		
6	Annual energy savings by providing daily/weekly/monthly feedback, energy savings tips to user and buy providing comparison with best practices	kWh/year	383
7	Standby power consumption of energy monitoring system	kWh/year	18
8	Net electricity saving	kWh/year	366
9	Total cost savings	Rs. / year	2,300
	Investment		
10	Cost of energy monitoring device that provides feedback and information through app	Rs.	6,930
	Payback		
11	Simple Payback period	Year	3.0

Based on above, it is estimated that installation of energy monitoring system will lead to energy savings of about 12% over the baseline situation. The simple payback for this investment is estimated to be 3 years.

10. Smart Outdoor Blinds

Features:

- **Ease of control**: Operate from anywhere using app.
- **Automation**: User can define automation control based on schedule or threshold value of global solar radiation (w/m2). For instance, the blinds can be programmed to close when global solar radiation is more than 80 w/m2.

Figure 57 Smart Outdoor Blinds

Techno – commercial analysis

a. Baseline

For baseline, four 2 BHK houses were considered in Design built tool and 8 windows of the bedroom were facing North (house 1), East (house 2), South (house 3) and East (House 4). The window size were considered as (4 feet x 6 feet) woth single glaze, 6 mm clear glass. No overhang was considered in this case. Based on simuation, annual electricity consumption of AC without any outdoor blinds was estimated to be 3977 kWh per year. The AC was assumed to be operating 5 hours during day time (from 12 PM to 5 PM, in summers and for some days in rainy season during high humdity conditions)

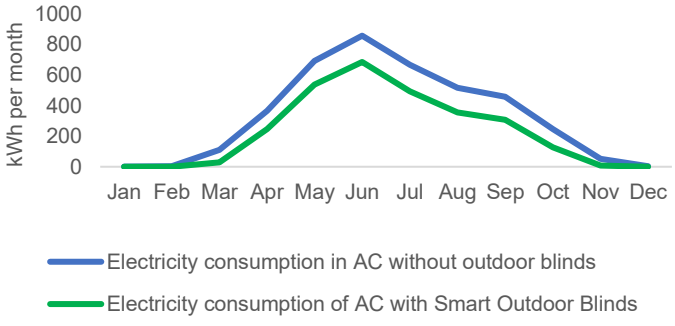


Figure 58 Smart outdoor blinds – simulation results

b. Energy and cost saving with smart outdoor blinds

For estimation of energy savings from smart outdoor blinds, in simulation it was considered as smart blinds will automatically close once the global solar radiation is more than 80 W/m2. Through this automation, the heat ingression, which was happening in baseline situation from 12 PM to 5 PM (coinciding with AC operations) has been minimized. Detailed calculation of techno commercial analysis of smart outdoor blinds is provided in table below:

Table 32 Techno - commercial analysis of smart outdoor blinds

S. No	Particular	Unit	Value
	Baseline - Without blinds		
1	No. of Windows	Nos.	8
2	Size of each window	Square foot	24
3	Glass type		6 mm, single glaze, clear glass
4	Total capacity of Split AC's installed	TR	4.8
5	EER of AC[39]	ISEER	2.3
6	Operating hours of AC during daytime	hours per day	5
7	Annual electricity consumption of AC without blinds	kWh/year	3,977
8	Tariff of electricity	Rs. / kWh	6
9	Annual electricity cost	Rs. / year	23,862
	Proposed solution - installation of smart outdoor blinds		
10	Annual electricity consumption of AC with Smart outdoor blinds, estimated based on simulation done in design builder software.	kWh/year	2,790
	Energy Savings		
11	Annual energy savings by use of smart outdoor blinds	kWh/year	1,187
12	Annual cost savings	Rs. / year	7,122
	Investment		
13	Cost of smart outdoor blinds	Rs.	33,600
	Payback		
14	Simple Payback period	Year	4.7

Based on above, it is estimated that installation of smart outdoor blinds will lead to energy savings of about 29.8% in existing AC over the baseline situation. The simple payback for this investment is estimated to be 4.7 years.

[39] Source: Baseline EER of AC, as per BEE report of impact of energy efficiency for year 2018-19.

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