A PRESENTATION
OF
SMART PUBLIC RESTROOM

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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

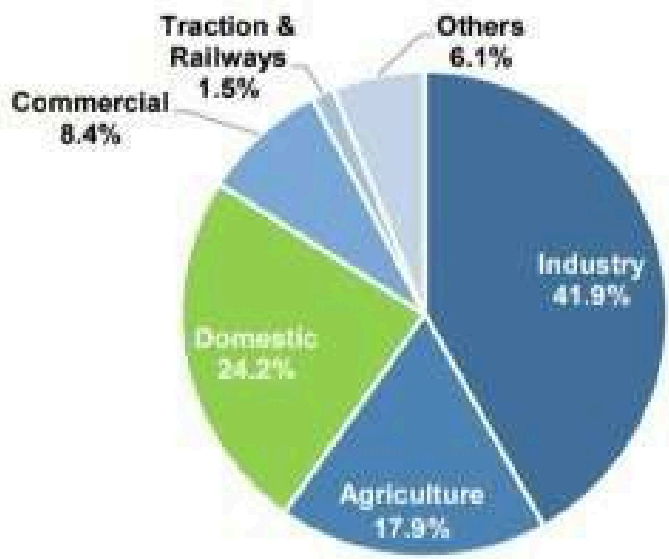

Figure 1 Sector wise electricity consumption in FY 2018-19, Source: Energy Statistics 2020, MOSPI

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[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

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.

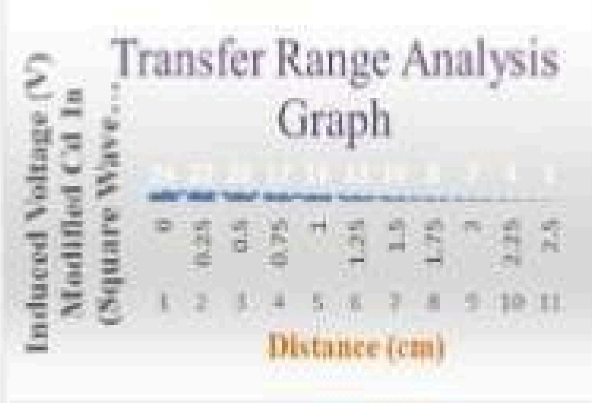

Figure-03. Transmission Range Analysis Graph

Table-04: Transmission Range Analysis

S.NO	Distance (cm)	Induced Voltage (V) Modified DC in (square wave form)
1	0	24
2	0.25	22
3	0.5	20
4	0.75	17
5	1	16
6	1.25	13
7	1.5	10
8	1.75	8
9	2	7
10	2.25	4
11	2.5	1

D. LCD Display Results

By LCD we can measure the (Voltage, Current, Temperature and Humidity), control the load, and can also Monitor Battery Status. The three modes touch LCD consist of consist of

I. Desktop mode

II. Control mode

a) Battery mode

Figure: 4: Main Menu

b) Desktop mode

In desktop mode control we can control the following components in users home and monitor the following alarms as shown in figure: 8

- Voltage
- Current
- Temperature

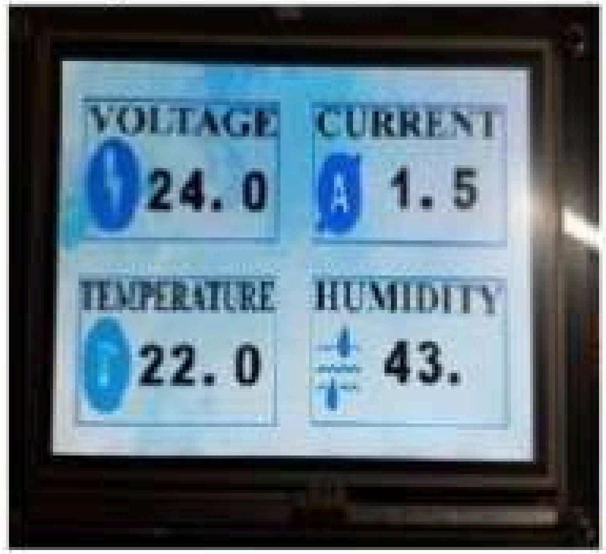

Figure 8. Desktop Mode

c) Control mode

In Control mode control the following appliance

- Lights on/off/dim
- Fan on/off
- On/off different appliance by touching buttons on touch screen LCD as shown in figure:9

Figure: 9. Controlling Mode

E. Battery mode

In battery mode we check the battery level and status either for charging or discharging and also check the battery percentage level as shown in figure:10 and figure:11 respectively

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:

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

The home security system consists of a master control panel, the keypad (when not using the qToggle app), motion sensors, and the siren. The qToggle app is provided with the options to arm and disarm the security system, as shown in **Figure 12b**. Arming and disarming can be performed by voice commands as well, using Google Assistant/smart watch. We have also implemented the Sleep option, which can be used during the night and arms only the ground floor of a house, for security reasons. If motion is detected downstairs during the night, the alarm will trigger. Arming and Disarming, using Sleep mode, can be done manually, using the qToggle app, but also using an extra light switch, placed upstairs (for more comfort). The alarm system used in this case study is a Paradox MG5050 alarm. A custom integration module has been developed using a Raspberry Pi board to be able to control the alarm unit remotely.

3.5. Controlling the Irrigations

Automated irrigation systems help people control the water used in their gardens or fields and, thus, to avoid water waste, to save energy and time, and to minimize water bills. Using an automatic system based on valves instead of the classical manual irrigation also avoids human errors, for example forgetting to irrigate one day, not being able to do it, or forgetting to turn off the water after irrigation. The proposed irrigation system is based on Raspberry Pi and controls a number of pop-up sprinklers. The system inside the well contains: electric valves (Rain Bird DV/DVF valves), one standard 1.1 kW water pump, a Raspberry Pi board connected to the house LAN, and a pressure switch (Easy Press II model, with a maximum pressure of 10 bar). **Figure** 13a shows how the irrigation system can be controlled using the qToggle app. The user is able to select two modes: the manual one where he can start and stop irrigations whenever he wants and in which zone he wants and an automatic mode, with or without humidity sensors (YL69 sensors from SparkFun, in this case, shown in **Figure** 13b).

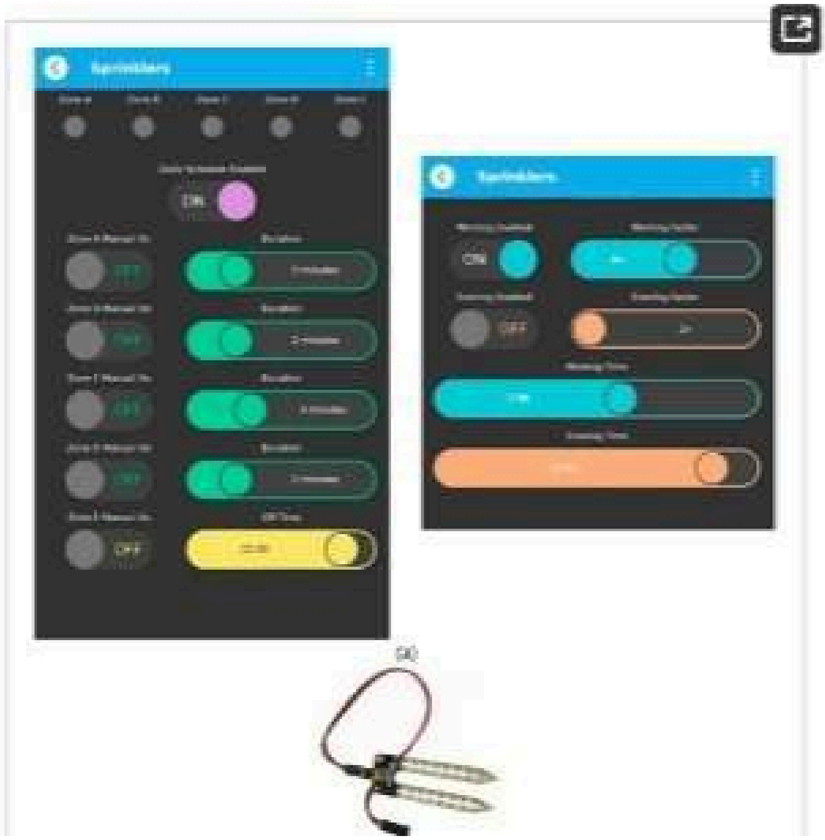
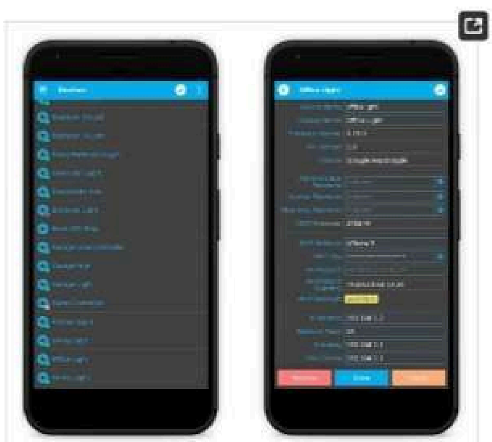


Figure 4. Creating panels (**a**) and groups of panels (**b**).

An example is given in Figure 5. The ports section is only accessible to administrators. In this section, the user may add, remove, and configure ports (see Figure 6). If users have slave devices management enabled in qtoggleserver.conf (by default they are enabled), the first thing they will have to do is to select the device whose ports will be edited. The first device in the list represents the hub (the master device) itself. An important fact is that only administrators can add, remove, and configure slave devices (see Figure 7).

Figure 5. Working with widgets: dashboard layout (**a**), widget properties (**b**).

Figure 6. Adding, removing (**a**) and configuring ports (**b**).



The purpose of controlling the indoor temperatures is to maintain thermal comfort and to save energy cost. In this case, the thermostats system offers the following advantages: the ability to access and control the indoor temperature anytime and from anywhere using qToggle app on the mobile phone, as presented in **Figure 8**a, the ability to monitor and separately set the temperature in individual rooms (not every room has the same heating requirements), and, finally, the ability to enable scheduling (lower the temperature during the day, when nobody is home, or during vacation). In this way, manual adjustments are eliminated to save time and effort.

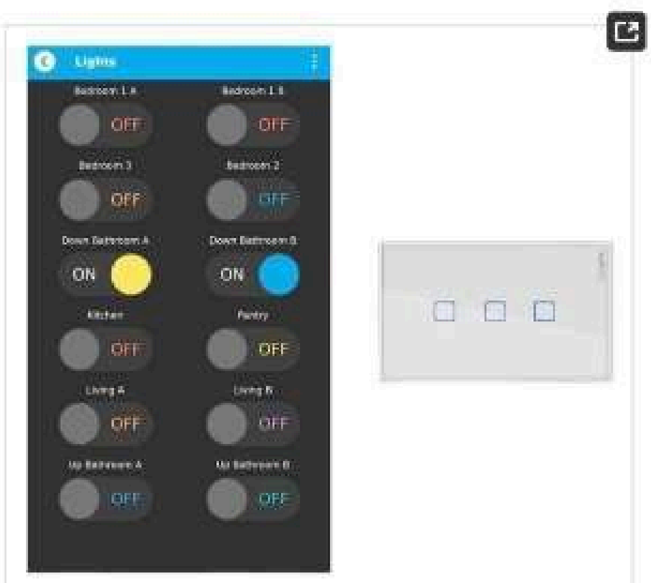
Figure 8. Controlling indoor temperatures with qToggle app (**a**) together with smart termostats (**b**,**c**).

This case study home is provided with nine smart thermostats. Thanks to temperature sensors, the heat system will start only when the temperature falls under a set value (this value is set on qToggle app, for each room). For this project, six Smart Wi-Fi Touch Thermostat Temperature Wireless Controllers, connected to the power line (shown in **Figure 8**b) and three Eqiva's eq-3 Bluetooth smart thermostats, which run on batteries, (shown in **Figure 8**c) have been used.

The A/C can be controlled to turn on and off without using the remote, by using the qToggle app. This task can be done using a smart plug for the A/C machine. Controlling the degrees is a feature that can be very easily implemented in qToggle, if necessary, and it will look similar to the case of thermostats.

3.2. Controlling the Lights

The proposed lighting control system on the qToggle app is shown in **Figure 9**. One of its main advantages is, of course, the comfort. Smart lights can, without any doubts, make our everyday life easier. Another advantage is related to energy saving. Big houses, with many rooms, can waste a lot of energy by simply leaving the lights on where they are not needed. In addition, many people forget the lights on somewhere in the house, when going to bed or leaving the house. In these cases, it is easy to see where lights are on and to control them using the mobile app. In addition, a smart lighting control system supports home security by providing increased protection. For example, this means that while away on holiday, the lighting system could periodically switch on and off lighting in the house, as if someone were actually home. The light can be controlled through qToggle app, or using Google Home assistant and the voice command "turn on/off the light in ... room". qToggle is compatible with Amazon Alexa as well. The devices used for controlling the lights are Sonoff Touch with one, two, or three channels.



Nowadays, the whole world is looking for sustainable and energy efficient solutions to make our planet greener, so the use of renewable energy sources, such as solar energy to the maximum efficiency possible is the best solution. Photovoltaic panels convert the sun's rays into electrical power and have become more affordable than ever. Combining the energy savings of solar systems with the smart technology, the benefit of renewable energy in a home is maximized. Home solutions can be fully automated using solar power. In addition to cutting energy bills and providing energy efficiency, solar power-based home solutions provide for the reduction of individual carbon footprint, give off zero emissions, and reduce overall environmental damage. For this case study, thirty-three photovoltaic (PV) panels have been installed, in two stages: the first sixteen panels (correspond to PV2 in **Figure 10**a, first panel, left), and then another seventeen panels (correspond to PV1 in **Figure 10**a, first panel, left).

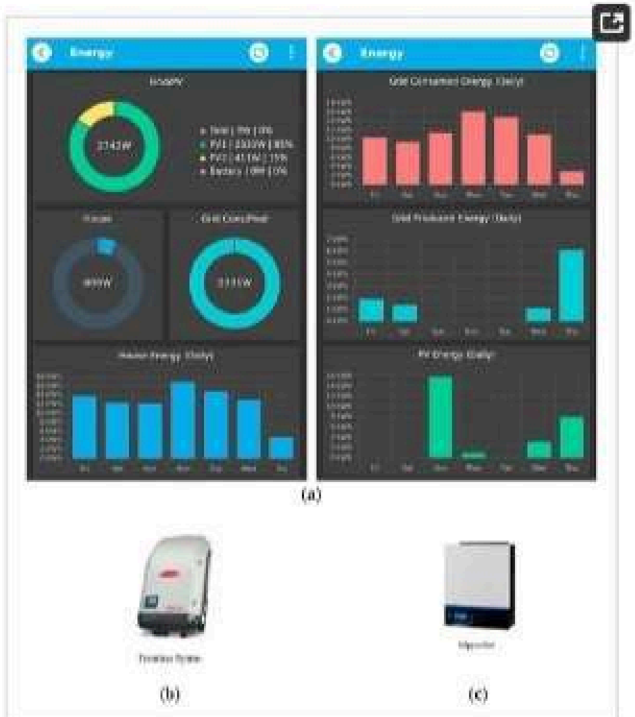
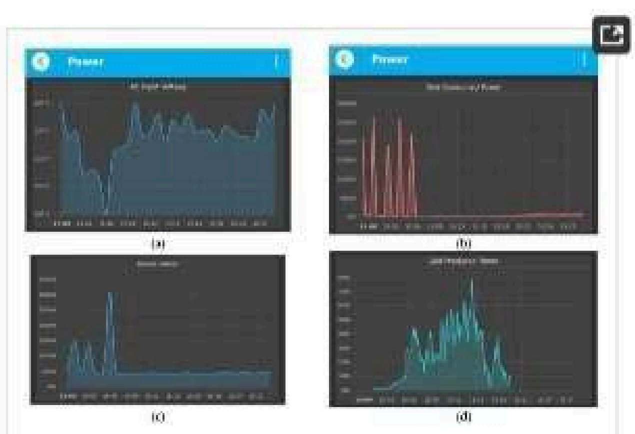


Figure 10. Monitoring the energy with qToggle (**a**) and the two invertors: Fronius Symo (**b**) and Mppsolar (**c**).

Solar installations require a dedicated solar inverter that converts solar power from the PV system into an alternating current. Inverters that are able to inject the excess of energy into the grid are called on-grid (or grid-tie) inverters and, in many countries, are subject to stricter rules than those that work off-grid. One of the most notable requirements for a grid-tie inverter is the anti-islanding protection: in case of a grid power outage, the inverter must immediately stop injecting energy, thus protecting electrical workers and upstream equipment. For this case study, the PV power inverters are from the following brand manufacturers: Fronius for PV1 (see **Figure 10**b) and MPPSolar for PV2 (see **Figure 10**c).

Solar energy can also be stored in batteries. When using batteries of a relatively large capacity, the energy accumulated over the day can be consumed during the night or during rainy days. Systems with smaller capacities may only be used as a backup, in case of grid outages, being able to supply the house with energy for a limited number of hours. An inverter that is capable of switching between grid, solar, and battery energy sources, depending on various configurable conditions, is called a hybrid inverter. MPPSolar is such a hybrid inverter.

The aim for monitoring the power is to see how much energy the house is using and to become more aware of the energy use and, thus, of the money spent. An electricity monitor also helps identify any high energy appliance accidentally left switched on. Moreover, an important goal of power monitoring is the detection of abnormal conditions in voltage when the electrical network is undersized, and there are a lot of voltage variations. A smart power meter allows a continuous monitoring of all the important parameters when it comes to electricity: active, reactive, or apparent power, power factor, current, voltage, frequency, and total energy consumption. The device is based on ESP8266 and integrates a high current switch that can be used to remotely cut off energy supply, in case of an emergency. **Figure 11** presents how the power is monitored using qToggle.



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

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[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

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:

Electric power can be transmitted by resonant inductive coupling or electromagnetic radiation and magnetic inductive coupling. Magnetic inductive coupling works on the principle of mutual induction like transformer works. [5-9].This theme is used for a shorter distance transmission and charging. Whereas electromagnetic radiation coupling is used for long-distance transmission [10-12]. As its receiver is not close to the transmitter, so this is not an efficient way of transmission. Much energy is consumed because of its omnidirectional property [13-14].

However, setting the coils to the same frequency in resonant inductive coupling can improve the range at which power can be transmitted efficiently with low complexity and without harmful effect [10]. The system capacity can be further improved through the simultaneous use of both inductive and resonant couplings to reduce leakage induction in the power flow path. Dual mode theory (CMT) [9, 11] and reflected load theory (RLT) [13-15] give a detailed analysis of the operating principles of wireless power transmission coupled with resonance.

Wireless power transmission provides a more convenient and environmentally friendly alternative to traditional plug-in charging because it has the ability to recharge all electrical-dependent devices within a medium-sized room with a single power source. This technology becomes relevant for electric vehicles and wireless sensors where it is practically impossible to operate the cables due to critical environmental conditions. Interestingly, this contactless method of operating electrical appliances is not only convenient and safe, but it also increases mobility and reliability at a low cost because it reduces the use of plastic and copper in wires [2]. In [24] numerous investigates that addressed emerging smart systems use Arduino, Zigbee, and raspberry pi strategies to read inputs - light on a sensor, a finger on a button, or a Twitter message or in building facial and voice recognition model.

This work on electronic devices completely covers the design, construction, and testing of a wireless power transmission system. The transmitter and receiver circuits are designed and implemented on printed circuit boards.

In this paper, an innovative IoT based communication infrastructure is proposed, and it provides two-way communication between the power block systems and the control system. The Power block defines how power is transmitted wirelessly transmitted by inductive coupling, we have two inductive coils, and power is transmitted like a transformer and also it depends on the number of turns and distance between coils. In controlling block simply, we are charging our battery by observing the relative parameters such as charging current, battery temperature, and device humidity level and to control three loads through IoT.

Section II discusses the methodology, Section III provides results and discussions and finally conclusion is given.

2.METHODOLOGY

The detailed architecture of IoT has been discussed by Author in [1]. Author has also highlighted applications of IoT such as its development in industrial Wireless Sensor Network (WSN) and especially its vast usage in smart home applications. Smart homes are those where household devices/home appliances could monitor and control remotely. When these household devices in smart homes connect with the internet using proper network architecture and standard protocols, the whole system can be called as Smart Home in IoT environment or IoT based Smart Homes.

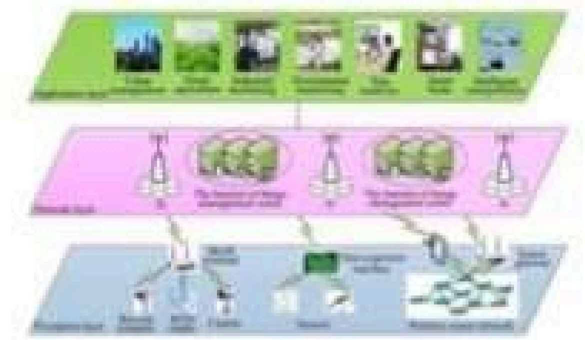


Figure 01: Architecture of IoT

The IoT-based wireless energy transfer system with Home automation consists of two blocks.

I. Power block

II. Block control and IoT (internet of things)

A. Power block

The power block consists of two modules: the transmitter module and the receiver module. The transmitter module which consists of 220-volt AC supply which is step down by the help of step-down transformer into 26-volt AC supply and then convert this AC Supply into DC by means of rectifier. Now that DC supply is converted into pulsating DC (in square wave form) through oscillator. The pulsating DC voltage (24.6 V) is transmitted through transmitting coil. In the receiver module, a receiver coil that receives the pulsating DC from the transmitting circuit in a square wave of 24.6 Volt and then filters the DC supply which is converted to pure DC 24.6 V.

The pure Dc supply output of receiver circuit is given to the controlling circuit where we charge our battery by the help of controlling circuit, but here we are waiting few seconds because, after transmitting the receiving module we have another controlling circuitry which is power up from battery, basically power up circuit measured the value of current and also creates the impedance. And the purpose is that, when we give battery current, it instantly sucks the current that affects the IC's (integrated circuits), SMD components either heat the IC's or raise the torque current, this is why we are waiting for impedance to meet the current 1.5 Amp and don't raise the voltage from 24 Volts, because of after rectification we are decrease the current and we are charge the battery. When the supply comes to relay coil, the relay coil does Work and the battery is charged. Once the battery starts charging a shunt, the resistor is also connected in series to the battery, which gives the voltage power current (1.5 amps needed to charge the battery). This is the charging cycle of battery. The Wireless Power Transfer System is composed of two independent transmitter and receiver circuits based on Proteus Software. The figure.2 and figure.3 demonstrate that the hardware is designed for

District cooling

A district cooling system[a] (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

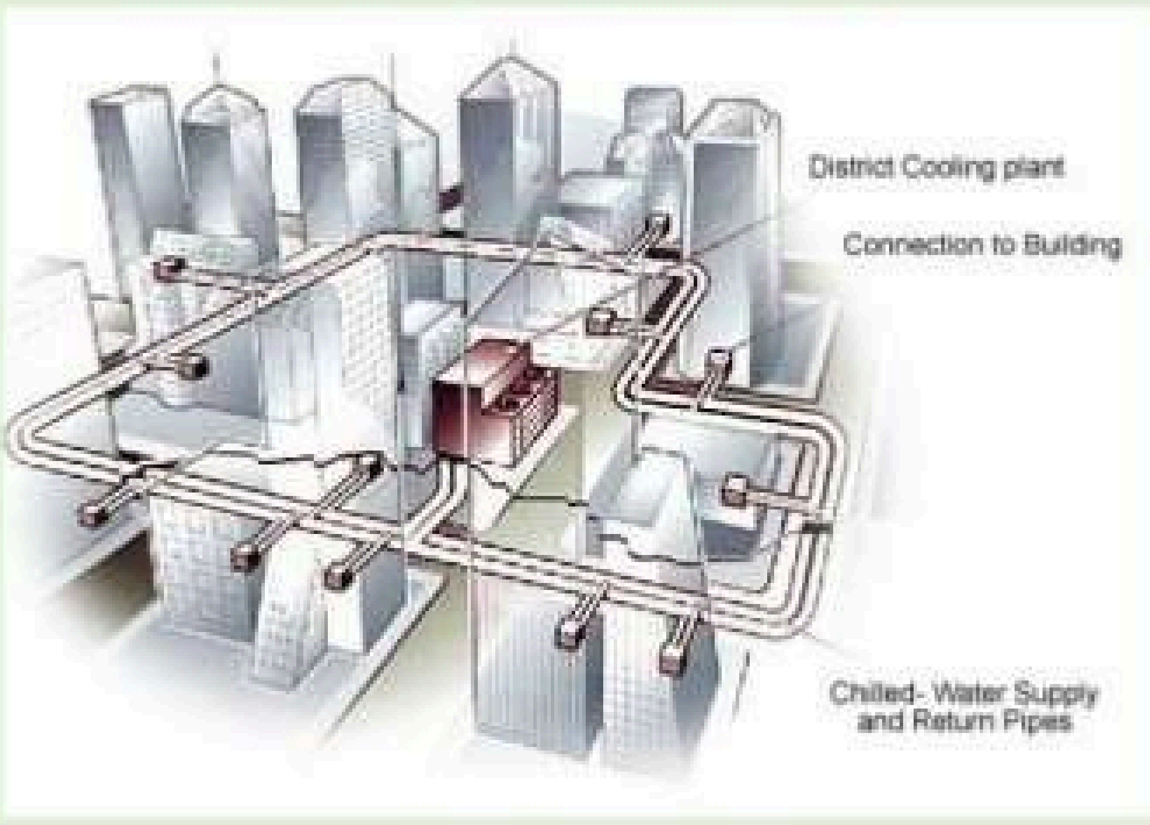


Figure 47 District Cooling System

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

Drivers

- Safety and security
- Convenience and life style
- Enhancement of home Interior
- Energy savings
- Penetration of smart phones
- Availability of high speed internet at affordable rates
- Changing work lifestyle
- Increase in disposable income

Barriers

- 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

Consumer related

- Limited awareness among consumers regarding energy savings
- Ambiguity about RoI
- Cost of acquisition of technology

Opportunities

- Availability and penetration of smart and connected appliances
- Need for health safety monitoring for children and elderly parents
- Managing renewable energy and energy storage
- Energy saving by preventing idle running and optimization of operating parameter
- Push for common standards across globe
- Cost of technology may reduce due to economies of scale.

Figure 16 List of drivers, barriers and opportunities

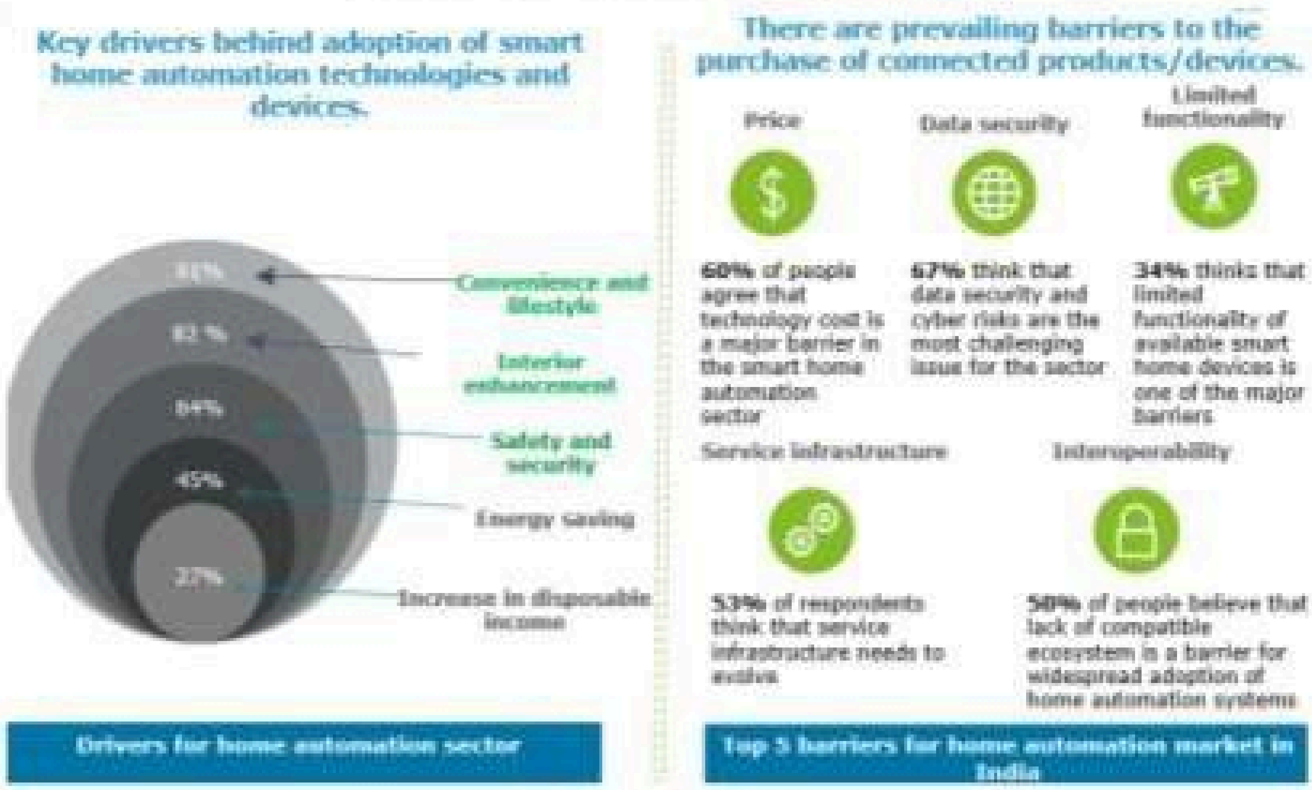
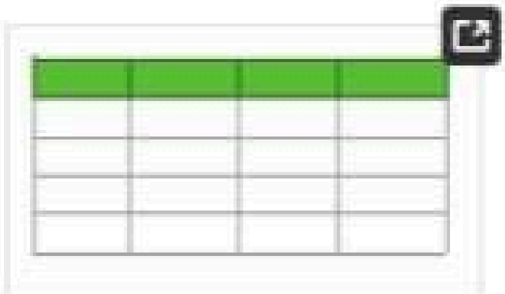


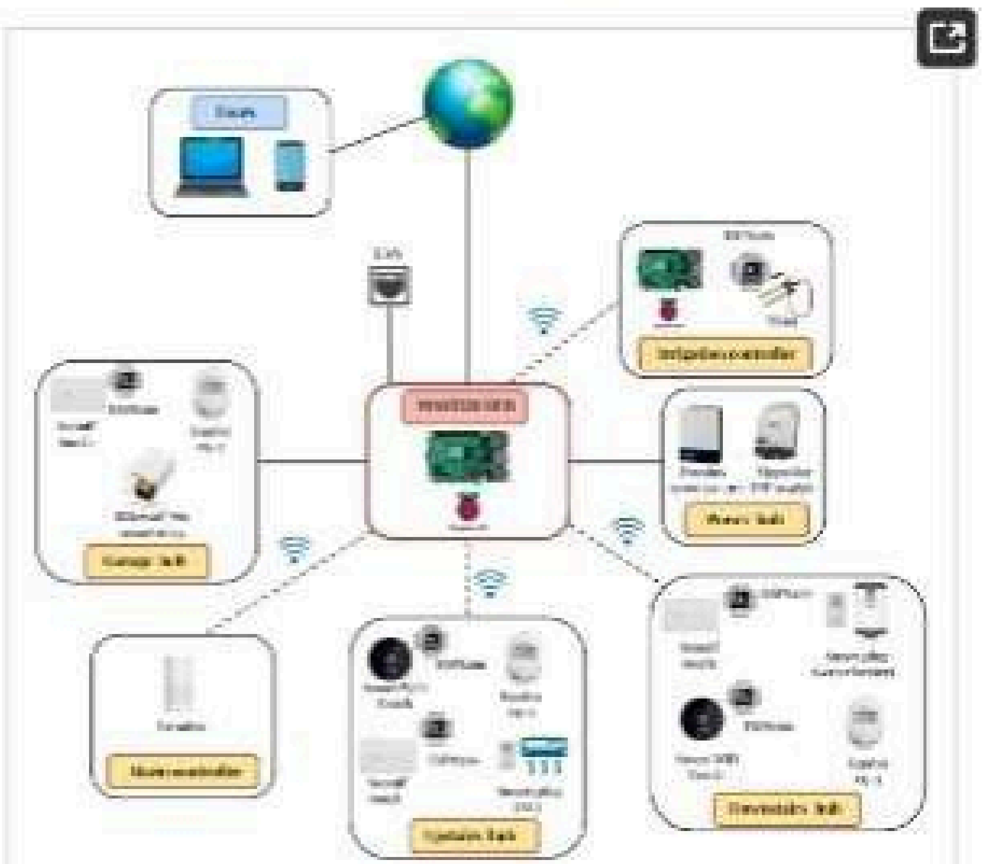
Figure 17 Quantitative analysis of drivers and barriers

- 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.

Table 3. Sensors and actuators used by qToggle for this case study.



The communication architecture for this case study is shown in **Figure 14**.



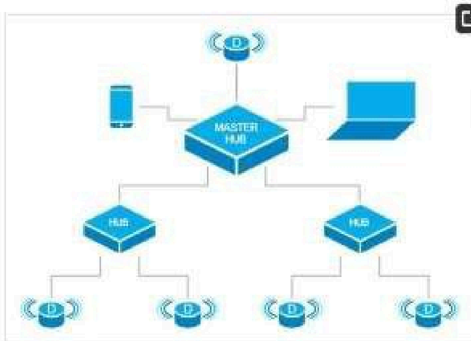


Figure 2. The qToggle topology.

In a real-world setup, it is difficult to individually manage many devices. Therefore, a hub will allow a centralized administration of devices used by qToggle. Hubs act as consumers when communicating to other devices, but they also expose an API interface that allows other consumers to see them as devices. This allows for the creation of complex hierarchies of devices and hubs that are in a master–slave relationship. With qToggle, a device may act as a master for other slave devices. The master controls slave devices and allows accessing them through its own API functions. In the same way, a slave device can act as a master for other devices. Thus, complex chained master–slave configurations can be obtained. Special API functions are supported by the master for listing, adding, and removing slaves. Slave devices are identified on the master by their names, but the master must be prepared for a slave's name to change at any time.

qToggle implements three roles that dictate the access level: the administrator role, which has the absolute power over a device, being able to view and modify the configuration; the normal role, which has no access the configuration but can read from/write to ports, and the view-only role that can only read the port's values. To facilitate automation, qToggle allows adding rules that dictate port values, based on various conditions. This means that a port can be taught to use an expression based on other ports and functions in a way that resembles spreadsheet formulas. Expressions can be set at a device level or at a hub level. Expressions on a device are very fast, but they can only depend on ports present on the device. When setting an expression at a hub level, the ports of any device that is known by the hub can be included. This will effectively implement relations between different devices. If consumers need to be notified about events that take place on the device, for example port value changes, qToggle offers three notification methods: listening for events using long HTTP requests (long polling), webhooks, and polling (the least efficient, but easiest to be implemented). qToggle setups are usually deployed in private networks, where devices cannot be directly accessed from the Internet. The solutions often depend on port forwarding, where public IPs are available. If port forwarding is not wanted/impossible, the devices can be set to open a connection to an external public server and to wait for API requests. This mechanism is called reverse HTTP and allows making HTTP requests to a device inside a private network without forwarding any port.

From a developer point of view, qToggle offers add-ons that are an easy and convenient way of packaging optional functionalities, which are usually tied to a specific device or service. Add-ons can be published or be kept private, depending on the developer's needs and licensing requirements. The entire source code is completely opensource [45], so one can easily understand how it works, may propose changes or may even join the team. In addition, we provide documentation on using and further developing qToggle for new devices or use cases.

Regarding the security, qToggle uses a series of best practices that are often found in nowadays web-based applications. HTTPS is employed for when a client from the outside (the Internet) talks to the hub. It ensures encryption, authenticity of the hub, and integrity of the HTTP messages. Plain HTTP is used only locally, inside the premises, between the hub and its controlled devices. A TLS certificate is used in conjunction with HTTPS to ensure the security goals mentioned above; Let's Encrypt is used to generate and renew the TLS certificates. This process is done automatically on the hub, upon certificate expiry. Remote (administrative) access on the hub is done via SSH. The SSH protocol uses ECDSA (or similar) private/public key pairs for authentication and encryption. Alternatively, the administrator password defined on the hub may be used to log in remotely with username and password.

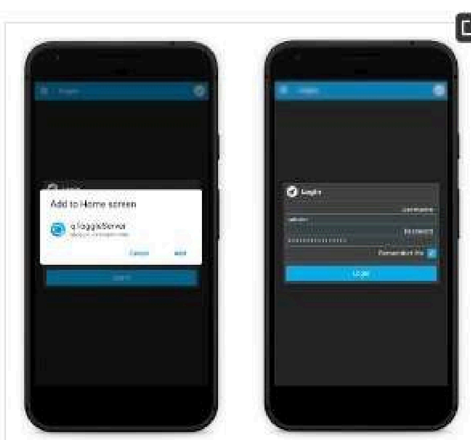
The API defines three roles that dictate the permissions of an API request: administrator, normal user, and view-only user. API requests use the JSON Web Token (JWT) defined by RFC 7519 to supply authentication data. A shared secret (called password) ensures the authenticity of the caller. The secret is hashed with a salt before used to sign the JWT token to prevent compromising the original password. Reply attacks are prevented by using the current timestamp as a nonce included in the JWT.

Alternatively, we could have used HTTP Basic Authentication, HTTP Digest Authentication, or a cookie-based session management with a conventional login form. Basic Authentication is insecure when transmitted over unencrypted channels, while Digest Authentication is unnecessarily complicated and requires exchanging multiple messages. The cookie/session-based method is prone to session stealing attacks and may also be insecure on unencrypted channels.

The embedded Over-the-Air (OTA) mechanism (firmware update) ensures that the hub as well as its attached devices always run the latest available version, thus allowing us to quickly bring security patches in case a vulnerability is discovered.

2.2. Configuring the Web Application

qToggleServer provides a user-friendly interface, named frontend, which comes in the form of a progressive web application (PWA). It is designed to be used on smartphones, tablets, but also on laptops/desktop machines. Firstly, the application should be installed and, being a PWA, it should be added to the home screen. After installation, the qToggle app will be found in the applications list of the device, and it can be uninstalled whenever the user wants to. When the user logs in for the first time (see **Figure 3a**), an admin with an empty password should be used. However, for security reasons, it is highly recommended to set a password in the Settings page of the app.



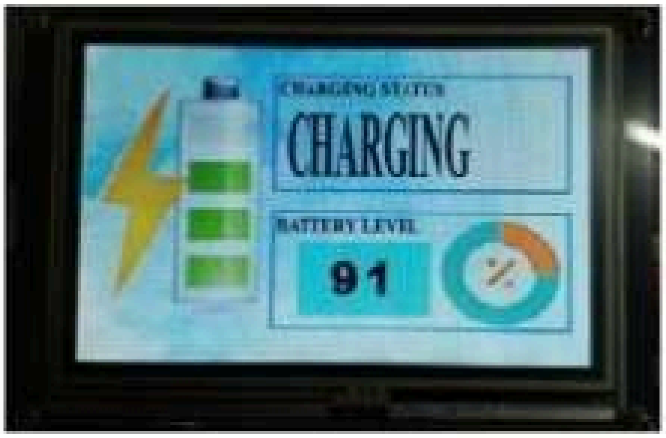


Figure.10. Battery Mode (Charging Status)

Our own domain (Private Domain) is used. We are building website print-end based on HTML / CSS and backend through PhP. From our hardware controller an API hit to the database from there and the second API hit to the front end indicates that we are having a full duplex of two APIs in short in our project, we are using two databases which implies that one database collects data from the controller and sends the data to another domain monitoring the data in a short one database used for monitoring another for monitoring purpose. We have an introduction page on the website, then we have a monitoring page for displaying our results and controlling the loads for our required condition by using our web app and monitoring the results in real time. Figure 12: shows the results on Domain

Figure 5. Results on Domain

4. CONCLUSION

The home automation using Internet of Things has been experimentally proven to work satisfactorily by connecting simple appliances to it and the appliances were successfully controlled remotely through internet. The designed system not only monitors the sensor data, like temperature, gas, light, motion- sensors, but the condition of various parameters in the home anytime anywhere.

The research is carried out on IoT wireless power transfer network with home automation in which we transmit and receive electrical signal through transmitter and receiver coils and charge our battery. Here we also monitor and control all battery parameters and the best thing about our project is that we minimize wire costs and can charge several charging devices at a time as well as eliminates the environmental threat posed by bad cord and cable disposal and short of circuits and we are the facility of charging of electric vehicle and smart lightning (home Automation) and we can control this all things from everywhere or every time 24/7 through internet, we can control and monitor loads on touch screen LCD as well as web domain, we can access domain by laptop, PC as well mobile phone through Wi-fi means doesn't matter that we are present near system or not we can control loads and monitor battery from every easily.

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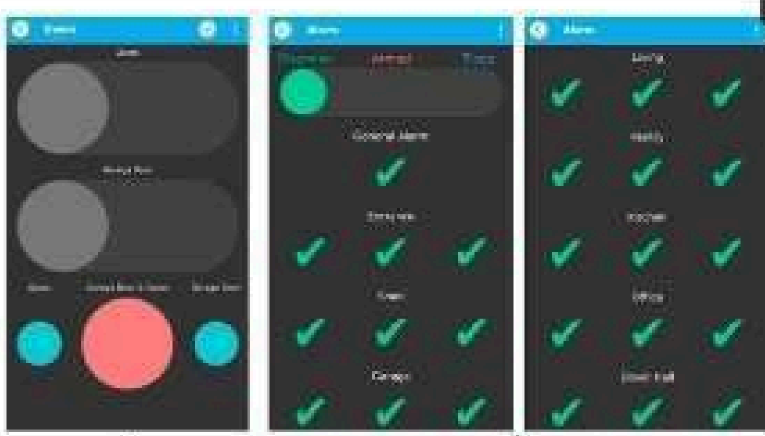
We consider that voltage monitoring is essential because the actual voltage supplied by the grid operator often varies from its nominal value, possibly causing faults to the electrical equipment. The chart (shown in **Figure 11**a) as well as its underlying historical data may serve as proof in case of appliance damage. The excess of solar produced power can be either used for household electrical necessities or it can be injected into the grid. Hence, we have the total house power (shown in **Figure 11**b), as well as the consumed and injected grid power (shown in **Figure 11**c,d).

3.4. Access Control and Security

Access control involves controlling entrances, gates and doors, in this case study, the gates and the garage door, specifically. Various options can be chosen: to fully open or close only the gates, only the garage door, or both at the same time, or to keep half open one of them or both, as shown in **Figure 12**a. Access control can be done manually, using the app, and by vocal commands, using Google assistant on a smart watch. To control gate motors and the garage door, we used two Blitzwolf SS1smart relay boards that enable remote opening/closing. This allowed us to mimic the conventional gate remote control using our Wi-Fi-based system.



the circuit of the transmitter module and the receiver module circuit, respectively, with its circuit components.

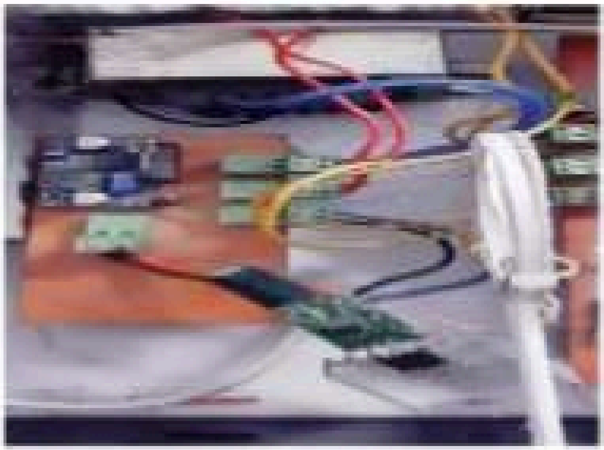


Figure-01: Transmitter module circuit

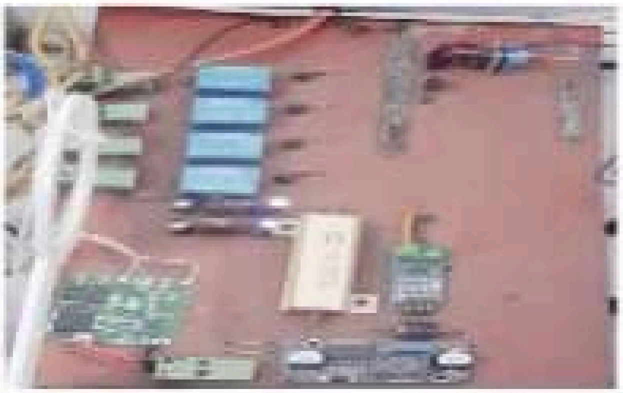


Figure-02: Receiver module circuit

Figure 14: Outside view of wireless power transfer based home automation

B. Control of blocking and the Internet of Things (Internet of Things)

First, in controlling the block section, we simply charge our battery by observing the relative parameters such as current charging, temperature of the battery and humidity level of the device. Then we use the graphical touch LCD for display purposes that involves a battery with a simple GUI (graphical user interface) for human access. We have shared hosting for our website in the IoT section where we have introduction page and then we have a monitoring page to show our results and manage the loads for our required condition by using our web app and monitoring the results in real time.

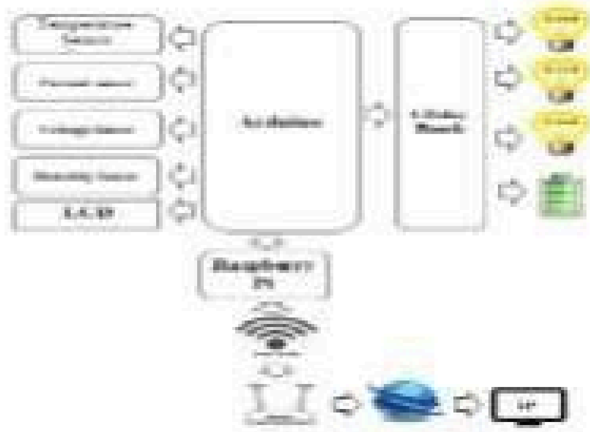


Figure 04: IOT Block Diagram

Figure: 4 shows the control block where Arduino mega controller is used and connected with humidity sensor, temperature sensor, current sensor, and voltage sensor and relay module. LCD is used for shows parameters, while Raspberry pi is connected to Arduino via serial communication which collects data and sends it to the domain proposed Home Automation System Functions

3.RESULTS AND DISCUSSIONS:

In this paper, the analysis of power circuit and control circuit done manually as well as IOT based. In the first part we measured all parameters manually with the help of multimeter and then in the second part we measured results internet of things based and showed them on Next Touch LCD and web domain as well as hardware structure is displayed.

C. Manually Results

In this section we have manually presented our results Table: 3 describes the performance of output Voltage Measurement of transmitter module

Table-03: Output Voltage Measurement of transmitter module

Parameters	Transformer Output	Rectifier Output	Oscillator Output
Voltage AC/DC	AC	DC	DC in Square wave
Actual (Volts)	26V	24.6V	24V

Transmission range was determined by varying the transmitter-receiver distance. A meter rule used to monitor the transmitter-receiver gap while a volt meter was used to determine voltage.

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

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.

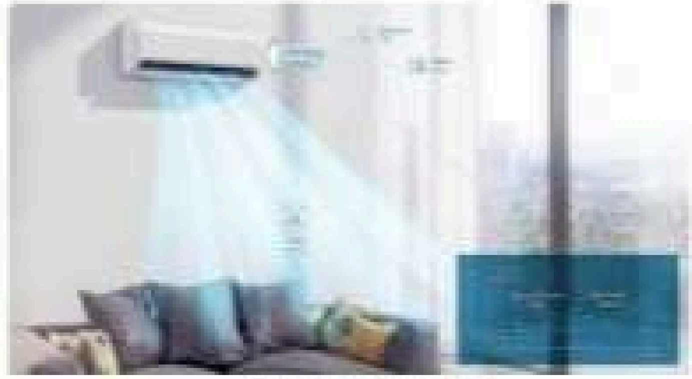


Figure 43 Smart AC

- **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[33].

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 °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 °C.

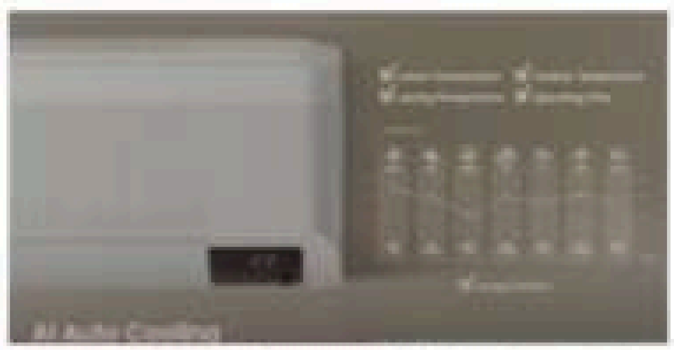


Figure 44 Smart AC – example of AI based controlling

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.

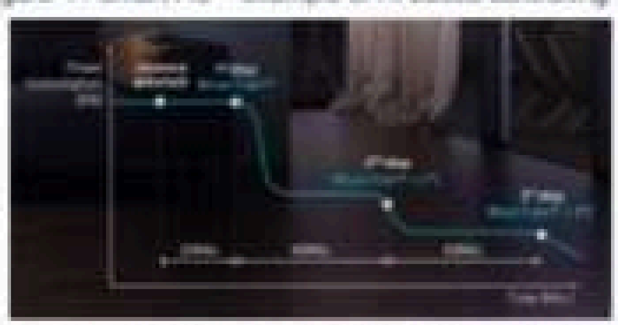


Figure 45 Smart AC – example of response to idle running

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

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:

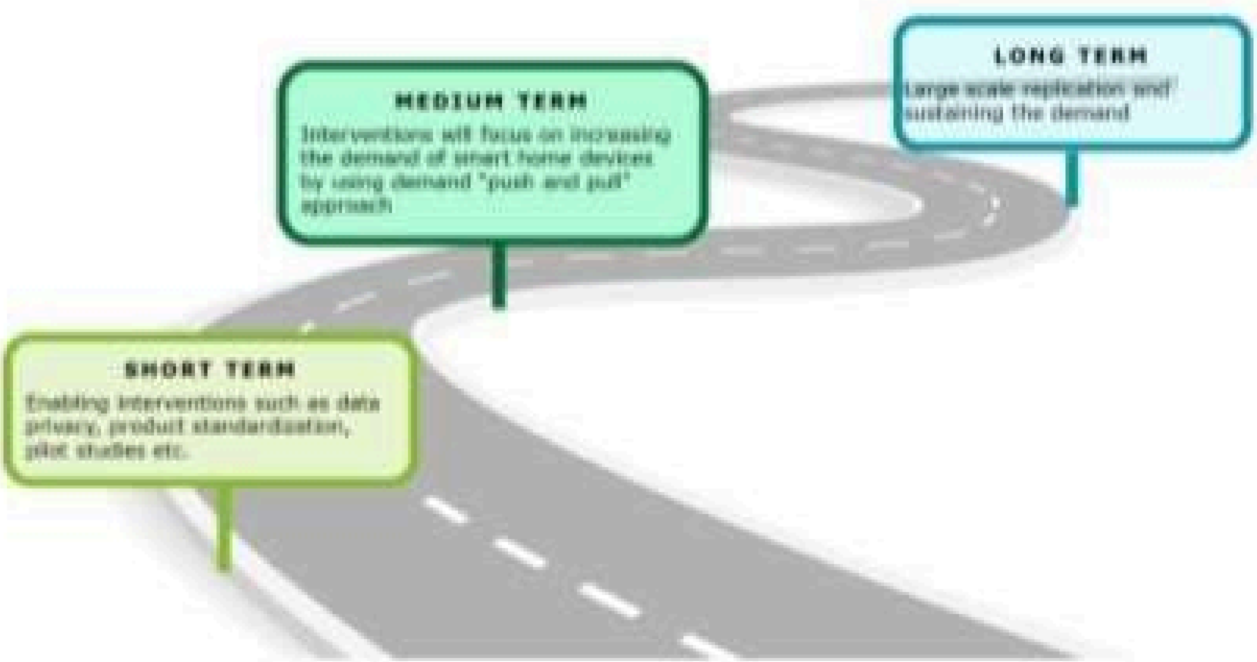


Figure 33 Classification of recommendations of national policy road map

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.

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.

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:

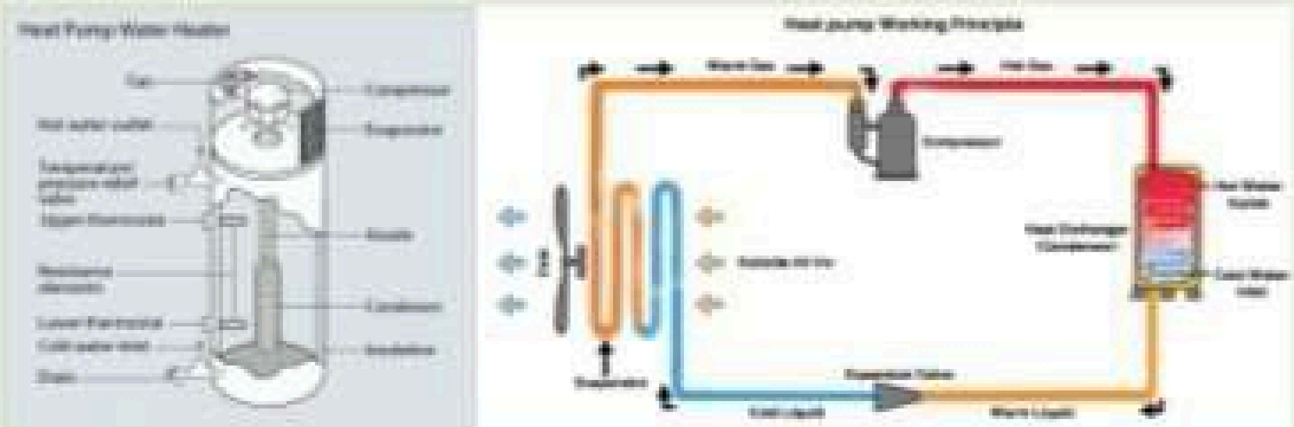


Figure 40 Heat pump based geyser

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:

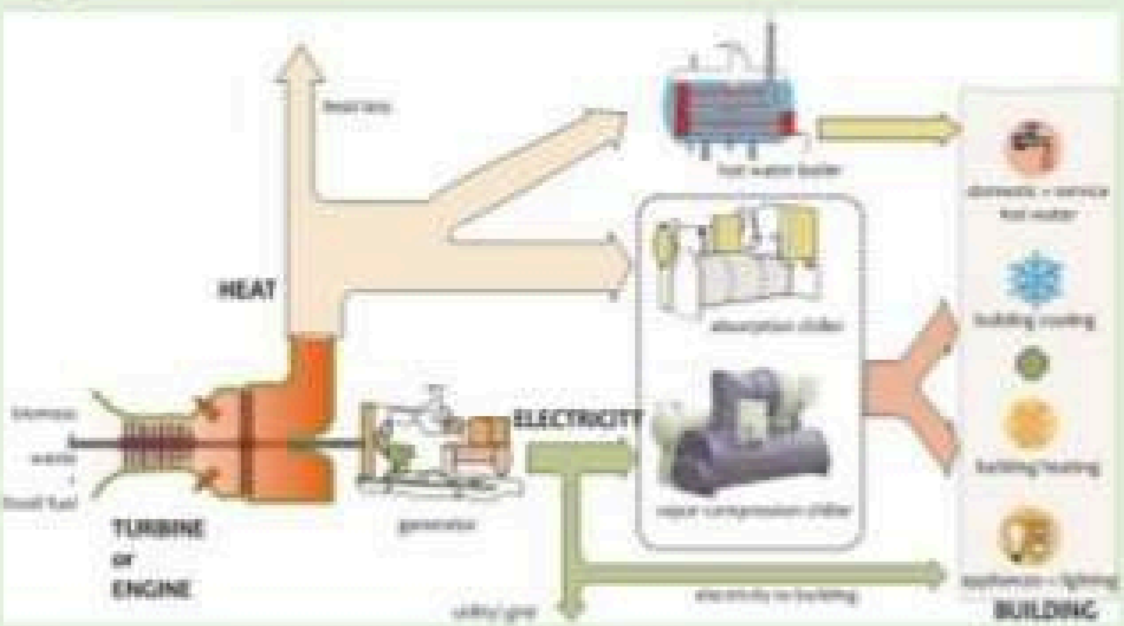


Figure 42 Tri-generation system for buildings

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

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:

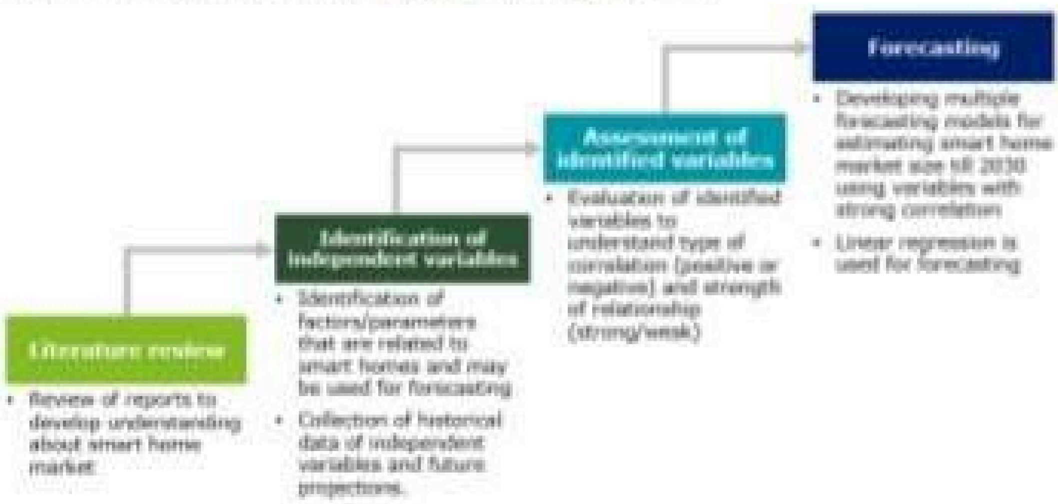


Figure 20 Methodology for market growth forecasting

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:

PROGRAM

```
# Import
necessary libraries for IoT and sensors import
time
import RPi.GPIO as GPIO
from Adafruit_IO import Client, Data
# Set up Adafruit IO credentials
ADAFRUIT_IO_KEY = 'your_io_key'
ADAFRUIT_IO_USERNAME = 'your_io_username'
aio = Client(ADAFRUIT_IO_USERNAME, ADAFRUIT_IO_KEY
)

# Define GPIO pins for sensors and actuators
motion_sensor_pin = 17
led_pin = 18
door_lock_pin = 23


# Initialize GPIO settings
GPIO.setmode(GPIO.BCM)
GPIO.setup(motion_sensor_pin, GPIO.IN)
GPIO.setup(led_pin, GPIO.OUT)
GPIO.setup(door_lock_pin, GPIO.OUT)


# Initialize door lock status
door_locked = False


def motion_detected(channel):
    global door_locked
    if door_locked:
        print("Motion detected, but the door is locked.")
        # Optionally, send a notification to the admin
```

```
def unlock_door():
    global door_locked
    GPIO.output(door_lock_pin, GPIO.LOW)
    door_locked = False
    print("Restroom door unlocked")

def lock_door():
    global door_locked
    GPIO.output(door_lock_pin, GPIO.HIGH)
    door_locked = True
    print("Restroom door locked")

# Set up an Adafruit IO feed for door status
door_status = aio.feeds('restroom-door-status')

# Main loop
try:
    while True:
        if GPIO.input(motion_sensor_pin):
            motion_detected(0)
        else:
            print("No motion detected.")

        # Read the door status from Adafruit IO
        door_status_data = aio.receive(door_status.key
)
        if door_status_data.value == 'unlock':
            unlock_door()
        elif door_status_data.value == 'lock':
            lock_door()

        time.sleep(1)
    GPIO.cleanup()
```

THANK YOU