A PRESENTATION OF TRAFIC MANAGEMENT

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An IOT based Smart Traffic Management System

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Abstract— *A smart traffic management is a wide topic of research. Many modifications can be made to make the urban traffic flow smoothly on the roads. The increasing utilization of private vehicles and public transportation due to advancement of technology causes hectic traffic complexities for the civilians across the globe. The problem of traffic congestion is an everyday problem for human resource and therefore hinders the growth of the country by affecting its productivity as well as economy. Moreover, the traffic signaling systems have predetermined fixed operational time which fails to manage the traffic density changing with time and thus, long traffic queues are formed at the road crossings resulting in increased pollution and waiting time. In this paper, we tried to provide solution to reduce the waiting time at road crossings while keeping in mind the importance of time of the citizens as well as the emergency service providers (such as EMS i.e. Emergency Medical Services, Fire and Rescue Services, etc.). The presented system in this paper is based on smart traffic congestion control system that will automatically set the signal time based on the measured values of vehicle density on road lanes. However, the manual changes can also be made to traffic signals for efficient traffic management in case of emergencies. This paper presents an idea of traffic management using internet of things (IOT). The Internet of Things (IoT) refers to a system of internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. This technology provides an effective communication between different signals and helps in collection of data thereby providing an IoT based smart traffic management system in terms of its automated tracking, monitoring and controlling of vehicles and its data processing.*

Keywords— ***Traffic management, Traffic Congestion, Internet of Things (IOT), congestion control.***

I. INTRODUCTION

In a world with growing population and increasing transportation needs, the cities need an intelligent traffic management system (ITS) which works based on traffic concentration on different lanes [1]. This system will be created to reduce waiting time at lanes and let the citizens travel to their homes, offices, schools and other destinations more quickly. The problem of unnecessarily waiting at signal, while other roads are empty is the cause of delay for people to reach their destinations. This problem is addressed here. The citizens will not be stuck in traffic for too long.

There is no live traffic monitoring developed for the citizens to be able to view the traffic status from anywhere. This system aims to provide the users with facility (maybe a website or an app) to view the actual traffic density and traffic status, like is there is no traffic, light traffic or very high traffic. This will help the people to decide on their path from whichever location they are current at. This will help them to avoid traffic and or pass through light traffic in order to get to their destinations.

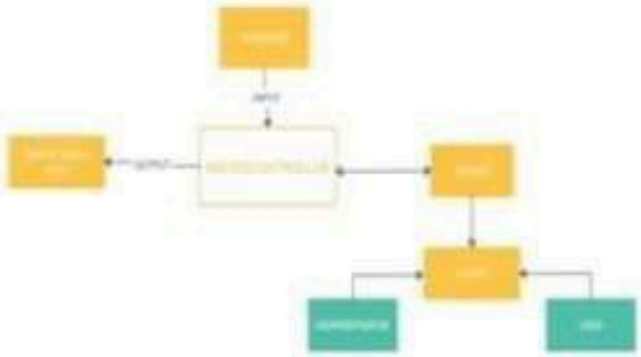
An emergency service has a very crucial role in people's life. In India, people always complain about the not getting ambulance, police, fire brigades and other lifesaving services on time. This system addresses this issue and gives the traffic control center people and authorities with a facility to manually control the traffic so that the citizens can get easy and fast access to the emergency services be it medical necessity, crime prevention measure or rescue services [2].

The project is an application of IOT. This system will reduce the waiting time of citizens at road crossings. It will allow users to monitor the traffic from anywhere in the world [3]. The user can monitor the traffic status from a website and chose the best path to take in order to reach his/her destination. It also aims to provide the citizens with emergency services more quickly by giving the manual control to authorities at traffic control station.

In this system, the idea is to make a three dimensional prototype model of a traffic signal system made on a solid cardboard. The LEDs representing traffic signal lights are placed at each intersection of a four lane road. The dividers placed beside each lane are mounted with IR sensors. The data from sensors will reach to the Control Centre (microcontroller), made nearby to road, and controls traffic lights (LEDs) accordingly. The Control Centre will automatically send live traffic data to users via website for monitoring. The authorized person will be able to change the green signal for emergencies

II. LITERATURE REVIEW AND FINDINGS

The Internet of Things is a novel paradigm shift in IT arena. The Internet is a global system of interconnected computer networks that use the standard Internet protocol suite (TCP/IP) to serve billions of users worldwide. It is a



network of networks that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic, wireless and optical networking technologies.

Fig.1: System implementation block diagram

According to Internet World Statistics, as of Dec. 31, 2011, 32.7% of the world's total population is using Internet.

In conclusion, the best definition for the Internet of Things would be: "An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment" [4].

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards. It is developed by Labcenter Electronics.

Web development is the building and maintenance of websites; it's the work that happens behind the scenes to make a website look great, work fast and perform well with a seamless user experience. The field of web development is generally broken down into front-end (the user-facing side) and back-end (the server side) [5].

A front-end development takes care of layout, design and interactivity using HTML, CSS and JavaScript. They take an idea from the drawing board and turn it into reality. The backend development uses computer programmes to ensure that the server, the application and the database run smoothly together. This type of development need to analyse what exactly the user needs are and provide efficient programming solutions. To do all this, developers use a variety of server-side languages, like PHP, Ruby, Python and Java.

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards [6]. The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

III. IMPLEMENTATION

The vehicle concentration or density will be detected by the IR LEDs and photodiodes. The controller will take the data from IR communication taking place in between IR Transmitter and IR Receiver. The microcontroller arduino nano will process this received data and show the signals through red, yellow and green LED's along with that controller will also ensure the delivery of the sensor data to users in form of a user friendly website where the people could watch the live traffic status.

For the manual control operation, the authorized person will send the request to the server with the login data i.e. the username and password. The server will match the user entered data with the pre-stored values, after successful

matching the server will open the page from which the user can set the direction in which he/she wants to display the green signal light.

The user after entering on the control page will be asked which mode of operation he/she would like to keep for the traffic. There are two options being provided one manual and the other is automatic. First, he/she have to select the manual mode and then as the user will click on opening a specific lane i.e. turning the green signal for that specific lane, the microcontroller will stop taking the data from IR Communication and will open the requested lane by showing the green signal in twenty seconds. When the authorized person is done its work, he/she will again have to set the control to automatic mode for the proper functioning of traffic. Then he/she can log out by clicking on the log out button, the server will redirect to the monitoring page.

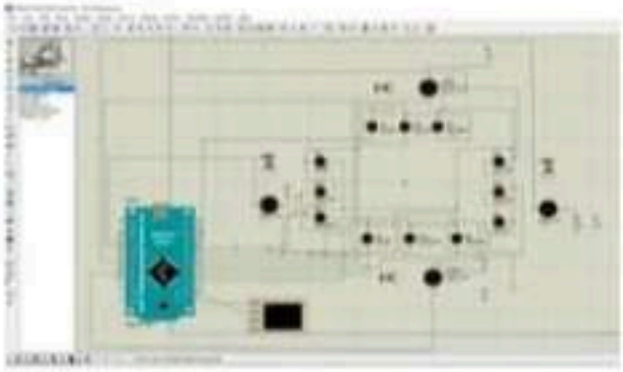


Fig.2: Circuit design on proteus simulation software

The circuit has been designed and configured with the help of Proteus Design Suite. The LEDs; red, yellow and green, are connected in the matrix of 4×3 where 4 represent the number of lanes and 3 represent respective LEDs. For the purpose of simulation and circuit design torch ldr is used as input collecting device. In the implementation of hardware the torch ldr's will be replaced by IR sensor (transmitter and receiver). The controller is also connected with virtual terminal which is acting as an IOT server. Just as how the user sends the request to server when once connected to web, we are also sending the request to virtual terminal and the virtual terminal it sends the response to user by displaying the messages on terminal.

IV. OPERATIONS OF THE PROJECT

The project as is an application based project, it has three major operations.

Automated Traffic Control-

This system works on the basis of traffic concentrations, the concentrations are divided into three levels, absolute no traffic, middle level of traffic, high density traffic. Broadly these three can be classified as follows:

Level 1: The absolute no traffic or zero traffic on road is known as level 1 traffic.

Level 2: The middle level traffic, i.e. the kind of traffic that ranges from one to five kilometres on road is known as level 2 traffic.

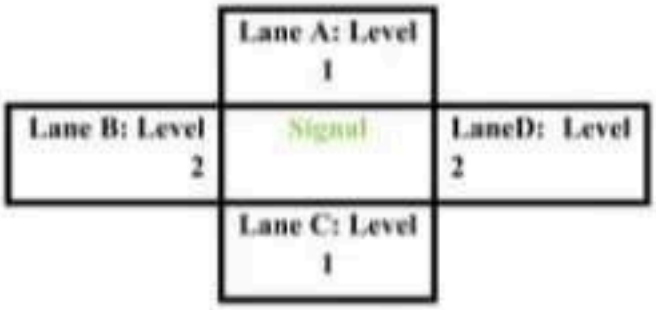
Level 3: The ranges higher than five kilometres come under level 3 traffic.

Operation on A four lane intersection road

Case 1: When there's Level 1 traffic, Level 2 traffic or Level 3 traffic on every road.

In such a case, the signal will run according to conventional sixty second fixed operational time. As the vehicle come on any one lane, it will show green second with in twenty seconds of time.

Case 2: When there's Level 1 traffic on lane A & C and Level 2 traffic on Lane B & D



In Such a case the signal will work according to sixty second rule on lane B & lane C and the lane A & lane C will always show red signal until level 2 traffic develop on these lanes. After the level 2 of lane B converts to level 1, and the lane A & C are still same, the green signal will only be shown on lane C, meanwhile, if traffic of level 2 develops on either lane A or C or on both, all the level 2 lanes will work according to sixty second rule until any of them reaches level 1 traffic.

Case 3: When there's Level 1 traffic on lane A, Level 2 traffic on Lane B & lane C, Level 3.

In this case the red signal will be shown on Lane A, until it reaches the level 2 traffic. Lane B, lane C and lane D will show green signal according to a fixed sequence of sixty second. If level 3 traffic develops on lane C, then also the traffic signal will show green signal to each of lane B, C and D at the interval of sixty seconds. In case lane A gets

level 2 traffic, all the four lanes will show green signal at the time interval of sixty seconds.

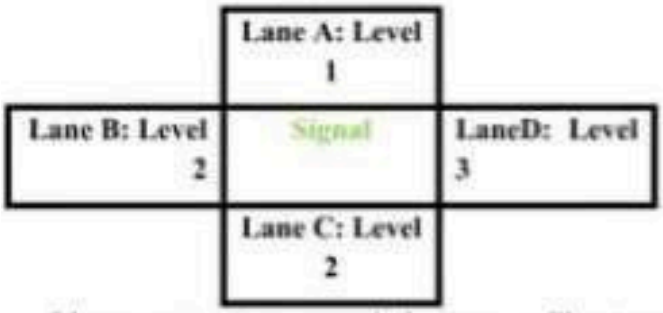
Live Traffic Monitoring

Any user with internet access will be able to view the traffic status of selected location through a website. The user will be able to monitor the category of traffic at specific area i.e. is the traffic density at that specific area is of level 1 type, level 2 type or level 3 type.

Authorized Manual Control

Fig.3: Live monitoring

The Traffic Management authority or any other authorised person will be able to login to the website as shown in figure 20. If any unauthorised person will try to login with



a fake username or password, the server will not open the control panel on the website page and will show an error message to the person. In case of only authorized login, the website will open the control panel and give control to the authorised person. The authorised person will get to open the lane of any specific lane i.e. he/she can turn green signal on for any one the of four lanes on a four-lane intersection road, in spite of the traffic density present there. This control section is being created for emergency purposes only.

Fig.4: Click on login to control

Fig.5: Input data will be checked from database and will be given access to valid login only.

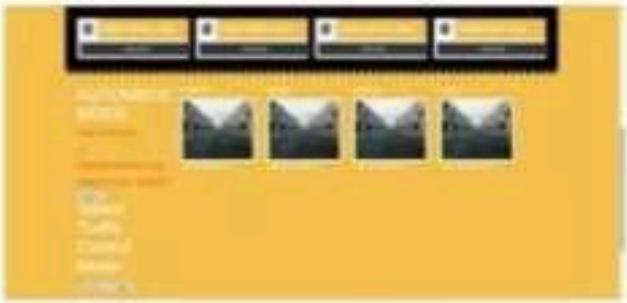


Fig.5: Authorised login will show this screen to manually operate the traffic.

V. RESULTS

The simulation shows all the three objectives, which were aimed to be developed, these includes:

1. **Automated traffic control according to density and monitoring**

The torch ldr will take input values and the microcontroller will fetch this data. Since, there are four direction and four torch ldrs, the direction in which the torch level is closest to the ldr, the green led will be shown by the last row of matrix, this will happen after the yellow light which is in the second row led will glow for the five seconds. The data will also be shown on virtual terminal, telling if the "lane number ('1','2','3' or '4')" , the signal is "yellow" and will also tell when the signal is "green".

2. **Manual traffic control according to density and monitoring**

Here, on the virtual terminal, by typing 'm', the controller takes input from the terminal only and not from the torch level. The user will press '1','2','3' or '4' and the light on matrix led of first row there will be three dots, showing the red LEDs, any one of the current three LED's the one will move towards second row and at the same the one led which was on the third row will move on the first row. The LED on second row shows yellow time which will move to the third row showing green signal of the selected lane number. This data will be shown on virtual terminal.

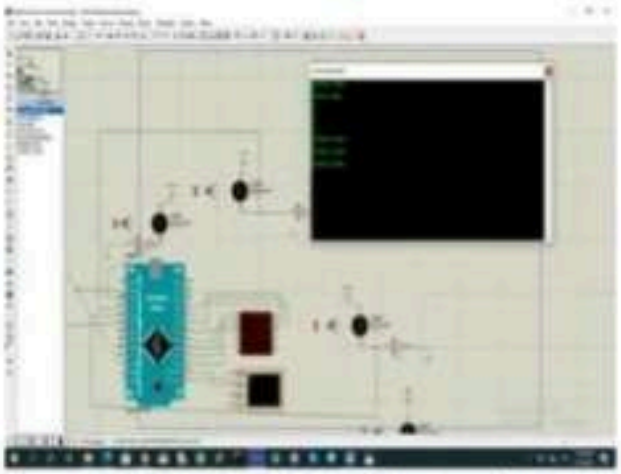


Fig.6: The final simulation result

The final hardware project also shows the three objectives that were aimed to be developed, these include:

1. Automated traffic control according to density

If the vehicles were placed on the roads as shown in the figure 7, the lane with the highest traffic density will get the priority and the green signal will be shown on that. If there are two lanes with middle range and high range traffic, both the lanes will be shown green signal one by one in the fixed interval of sixty seconds. In case of high range traffic, middle range traffic and low/ no traffic, all the signal will show green signal one by one for the duration of sixty seconds each.

2. Monitoring of the live traffic

The traffic can be monitored with globally accessible website on the internet with the name www.tlms.atwebpages.com. The website to monitor traffic is shown in figure 48 on page 46.The website shows on which dire the green signal is currently on. It also shows the density level of the traffic signal i.e. it shows whether the signal has no traffic, middle level traffic or high traffic on each of the directions; North, South, East and West.

3. Manual controlling of the live traffic

The user with the registered username and password will be able to log in to the same website as described in above point. The user can open any lane i.e. turn on green signal for any of the four directions. This is only for the cases of emergencies.

Fig.7: The final system

VI. FUTURE SCOPE

Though the prototype model worked very efficiently with remarkable outputs, the real life situation is going to be way more challenging and demanding. Few of the challenges that should be taken into account are listed as follows

1. Low range IR sensors may not be an answer for long range signalling system. We may resort to ultrasound, radar techniques or digital image processing technology for large scale set-ups.

2. Next is the influence of stray signals that may alter the reading of sensor receptors and lead to conveying false information to the microcontroller.

3. Periodic checking of the accuracy and precision is a must for efficacious operation

VII. CONCLUSION

Traffic management is one of the biggest infrastructure hurdles faced by developing countries like India today. There is an exigent need of efficient traffic management system in our country, as almost every indian waste their precious time getting stuck in traffic. To reduce this congestion and unwanted time delay in traffic, an advanced system is designed here in this project. With field application of the IOT technology, the maddening chaos of traffic can be effectively channelized by distributing the time slots based on the merit of the vehicle load in certain lanes of multi junction crossing. We have successfully implemented the prototype at laboratory scale with remarkable outcomes.

With this project, the idea is spread to set green signals in accordance with the type of traffic concentration; this would save the time of common people and some of health issues like headaches because of the noises being generated on the roads when stuck in traffic. People keep on banging their cars and other vehicles horns. This project emphasizes the importance of IoT based congestion control, live traffic monitoring as well as the controlling of the traffic manually.

The next step forward is to implement this schema is real life scenario. We believe that this may bring a revolutionary change in traffic management system on its application in actual field environment.

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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. Schematics of heat pump based geyser and working flow is provided in figure below:

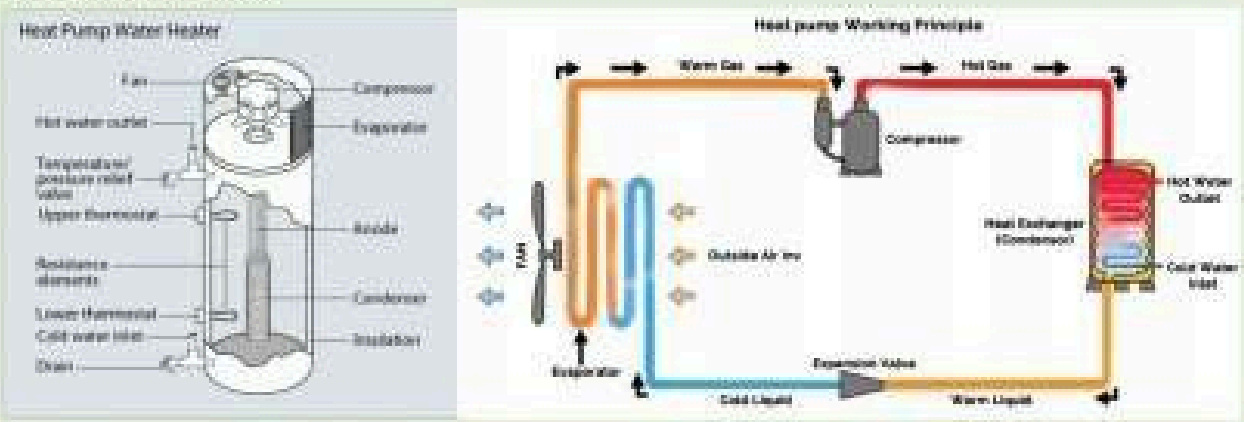


Figure 40 Heat pump based geyser

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:

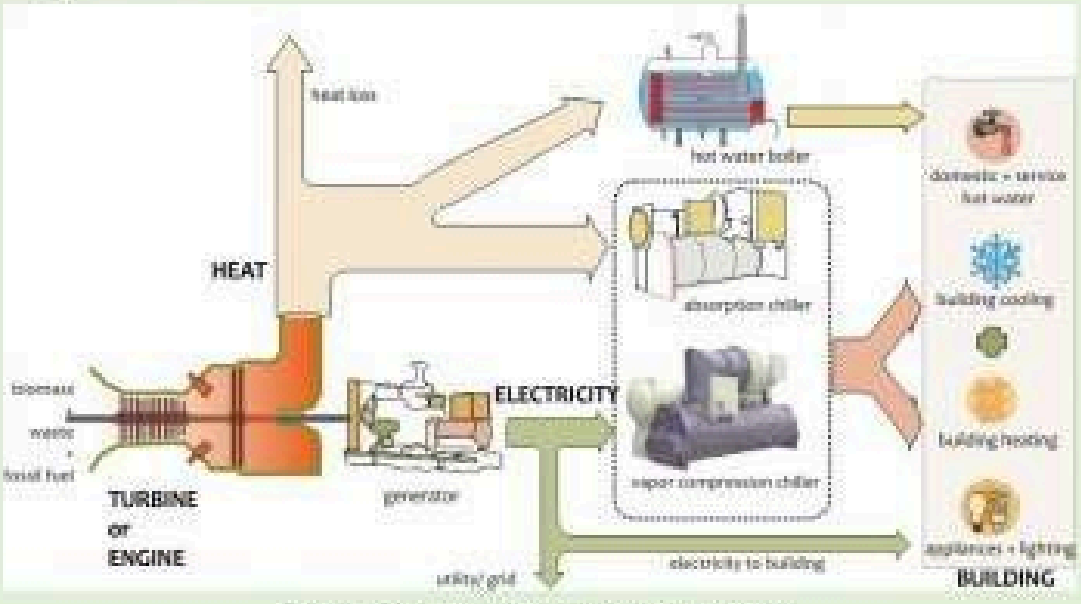


Figure 42 Tri-generation system for buildings

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

Figure 43 Smart AC

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 provisions 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.

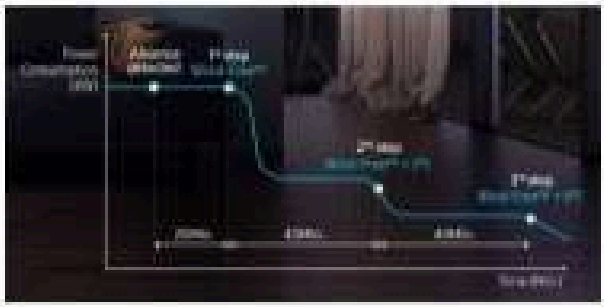


Figure 45 Smart AC – example of response to idle running

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

Drivers	Barriers	Opportunities
• 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	• 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	• 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

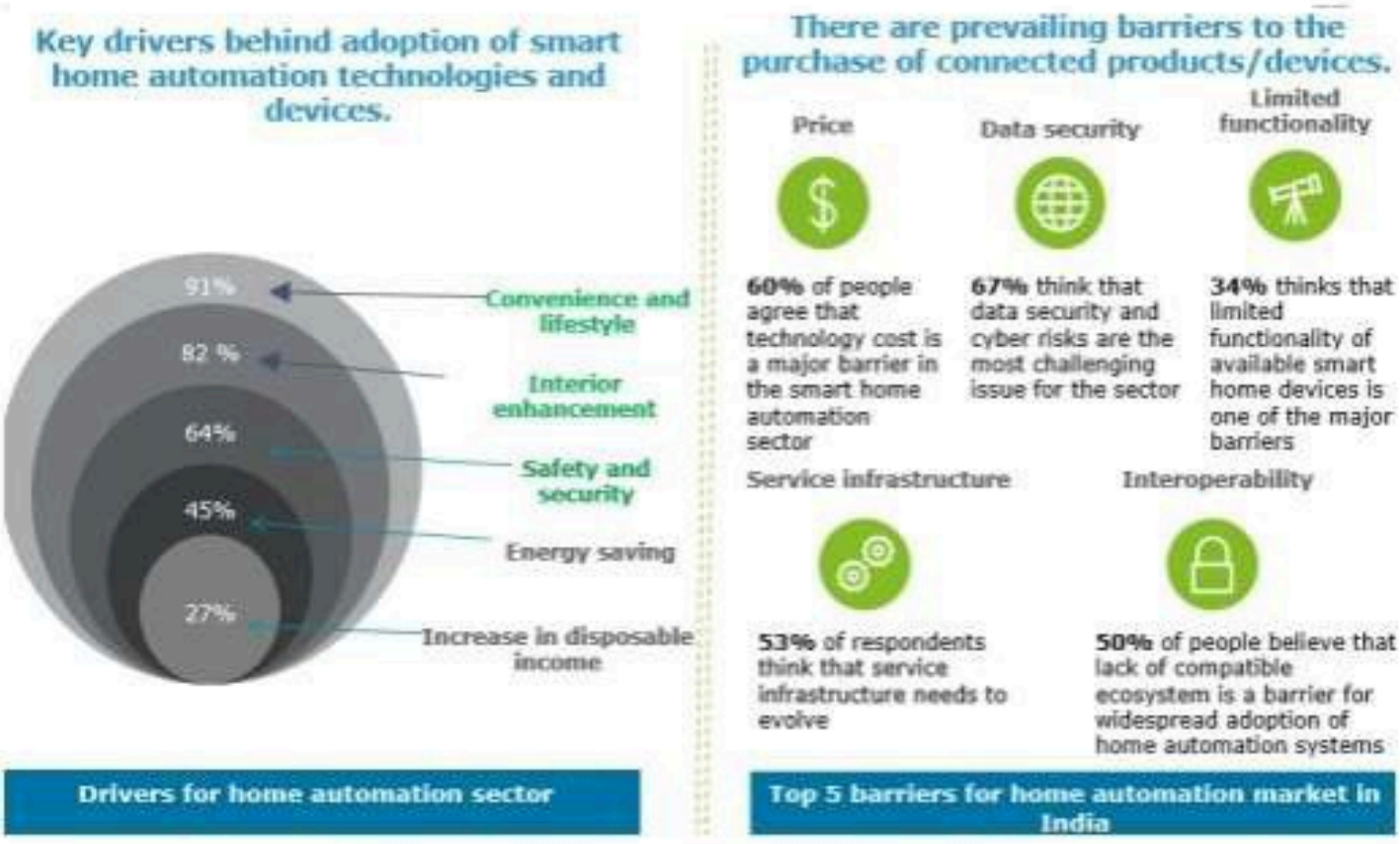


Figure 17 Quantitative analysis of drivers and barriers

- 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.

(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:

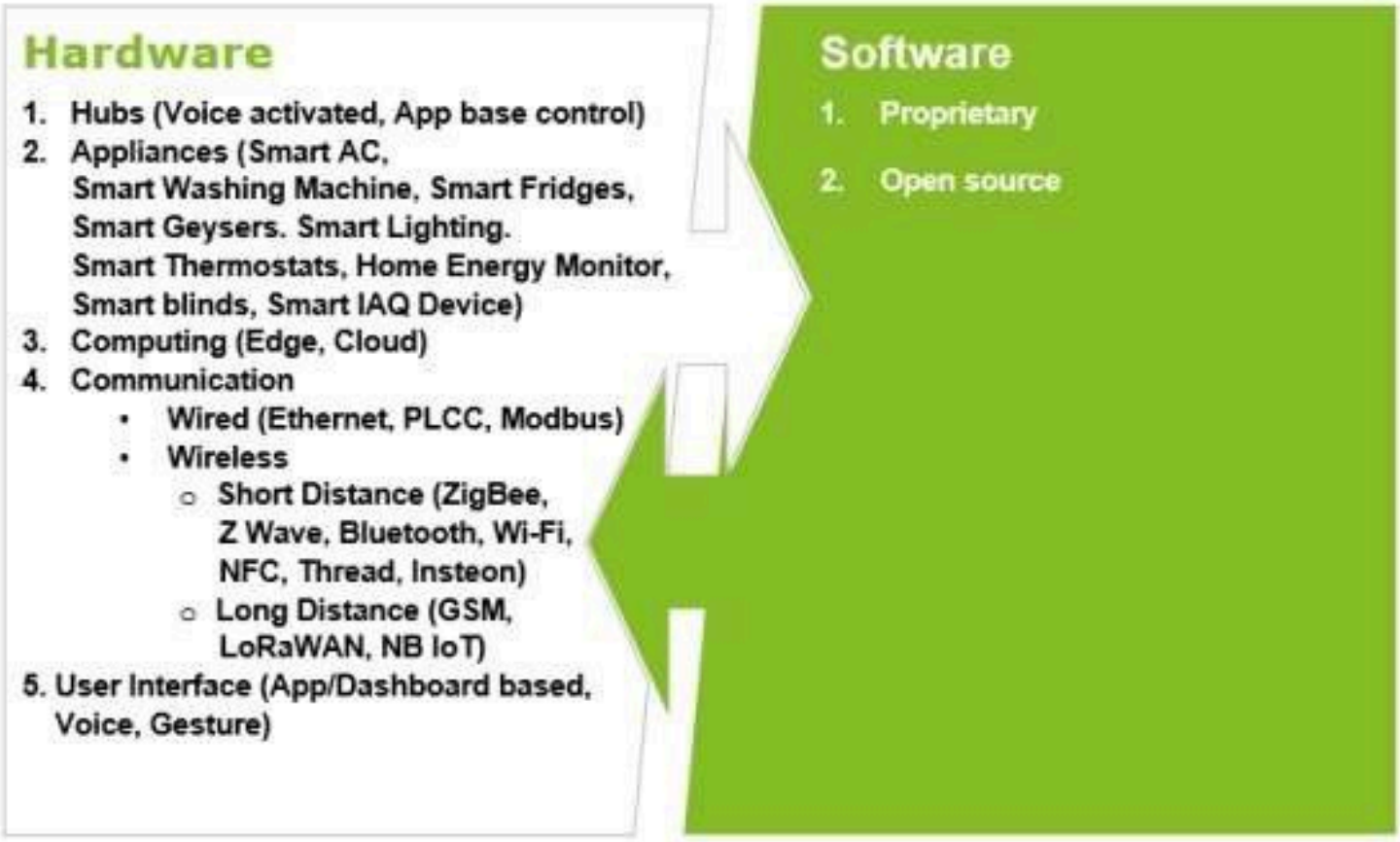


Figure 7 List of hardware and software technology mapped and reviewed

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

2. Smart homes as a service

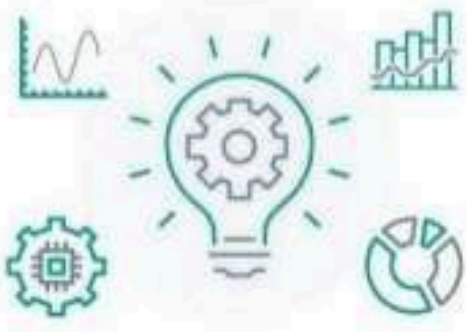
Smart homes are being sought to be provided as a service that is driven by utilities, telecoms and cable network providers. Smart home technology is more about the overall system – the services provided – rather than the connected devices themselves. Consumers want the benefits without having to master 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 boking 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.

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

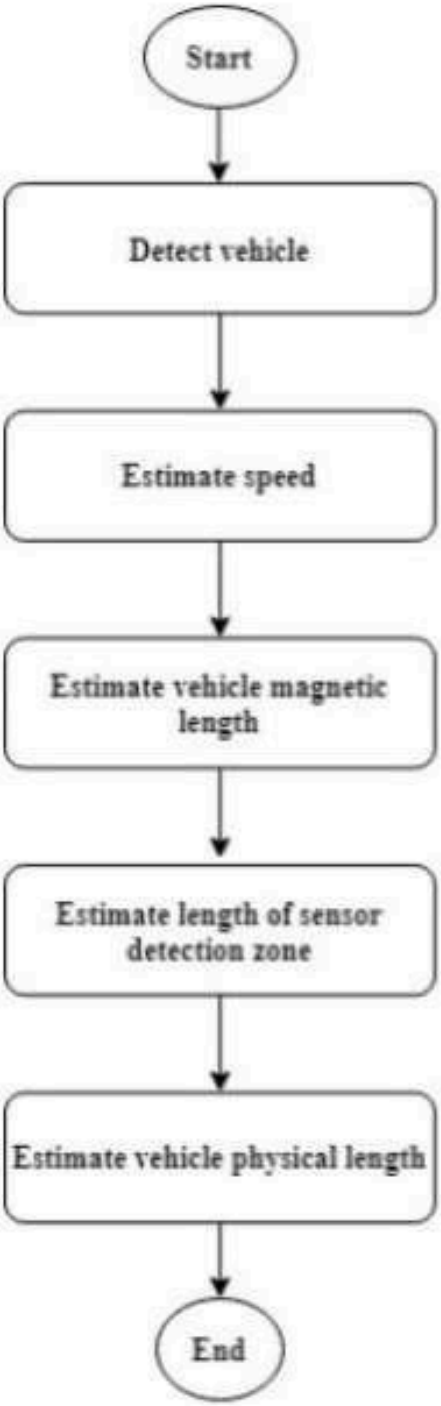
For estimation of energy savings from energy monitoring, following provisions were considered in calculation

- Energy saving potential of energy monitoring system is considered as 12%[36] 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.

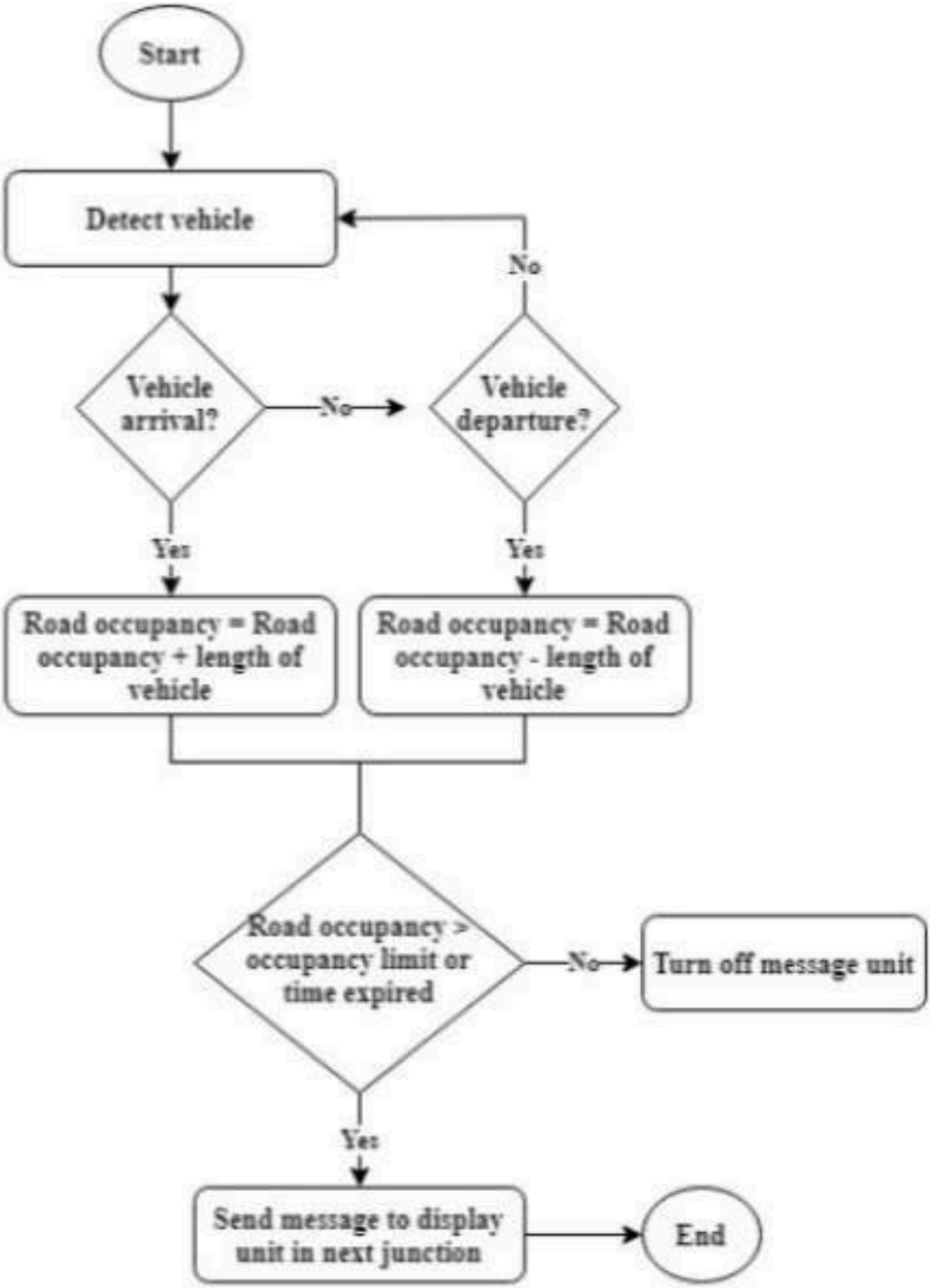
Detailed calculation of techno commercial analysis of energy monitoring system is provided in table below:

Table 31 Techno - commercial analysis of energy monitoring system

Figure 56 Energy monitoring system - Hardware installation


Start
Detect vehicle
Estimate speed
Estimate vehicle magnetic length
Estimate length of sensor detection zone
Estimate vehicle physical length
End

a)


Start
Detect vehicle
No
Vehicle arrival?
No
Vehicle departure?
Yes
Yes
Road occupancy = Road occupancy + length of vehicle
Road occupancy = Road occupancy - length of vehicle
Road occupancy > occupancy limit or time expired
No
Turn off message unit
Yes
Send message to display unit in next junction
End

b)

APPLICATION LAYER: CUSTOM APPLICATIONS

TRAFFIC ADMIN DASHBOARDS

MESSAGE DISPLAY UNITS

SERVICE LAYER: DATA STORAGE, OFFLINE PROCESSING & VISUALIZATION

NETWORK LAYER: COMMUNICATION, WIFI, MICRO CONTROLLER

NODEMCU ESP8266

SENSING LAYER: VEHICLE DATA COLLECTION &PREPARATION

HMC5883L MAG

HMC5883L MAG

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

Schematics of edge computing architecture is provided in figure below:

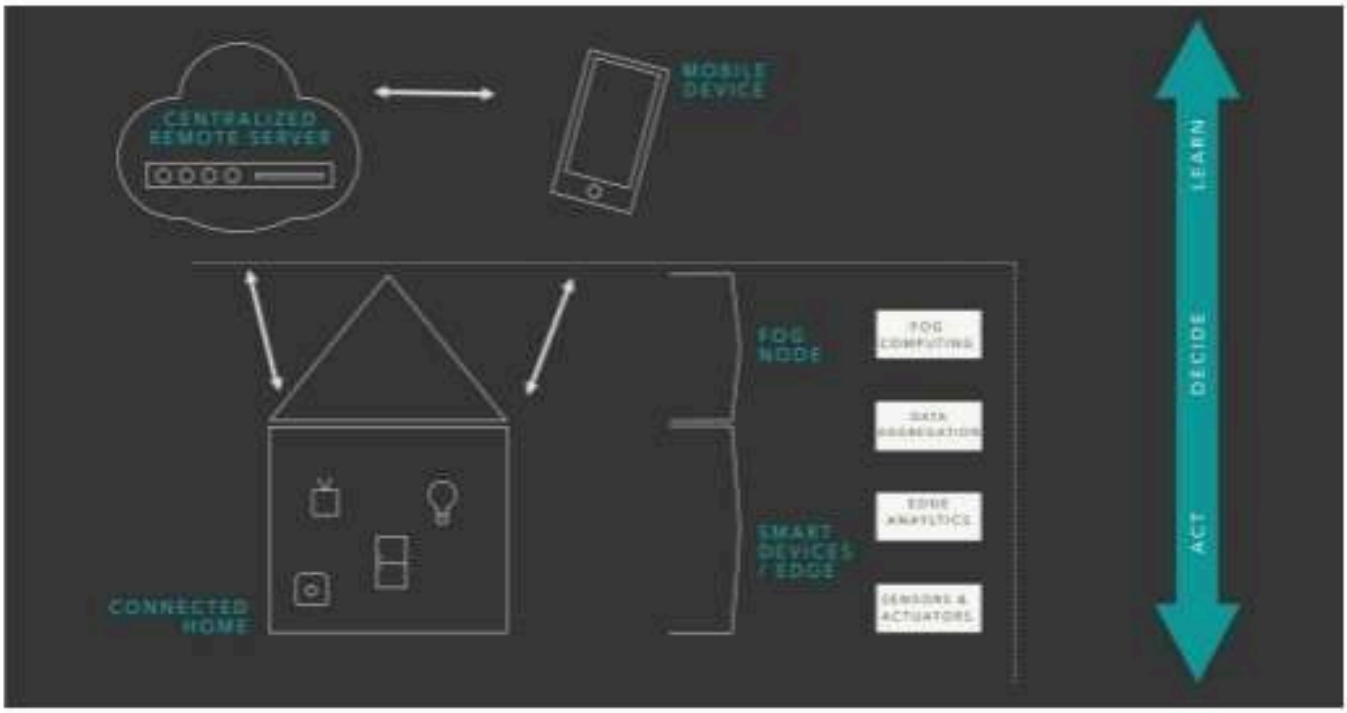


Figure 12 Schematics of Edge computing architecture

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:

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

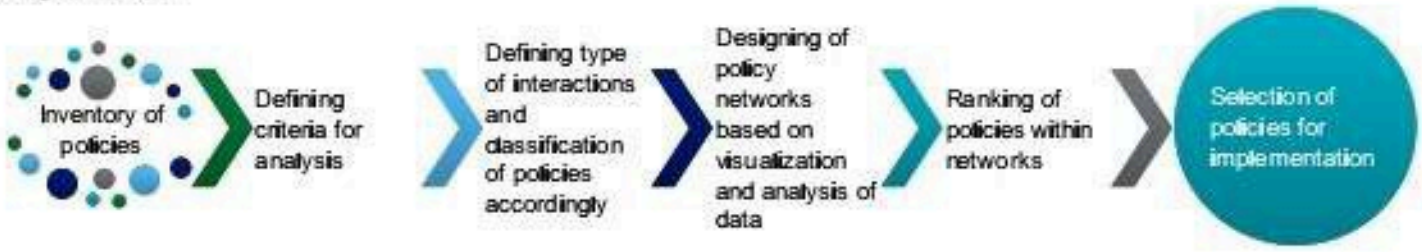


Figure 32 Methodology for shortlisting and prioritizing recommendations

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:

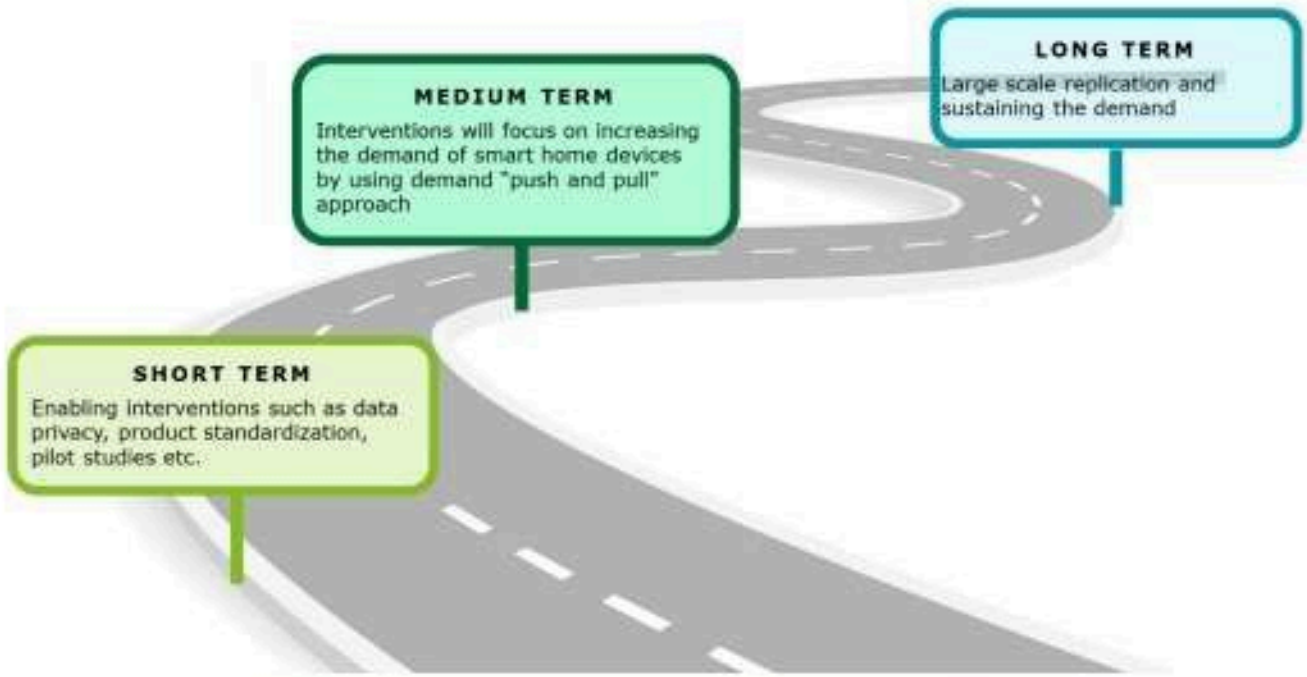


Figure 33 Classification of recommendations of national policy road map

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.

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. Schematics of heat pump based geyser and working flow is provided in figure below:

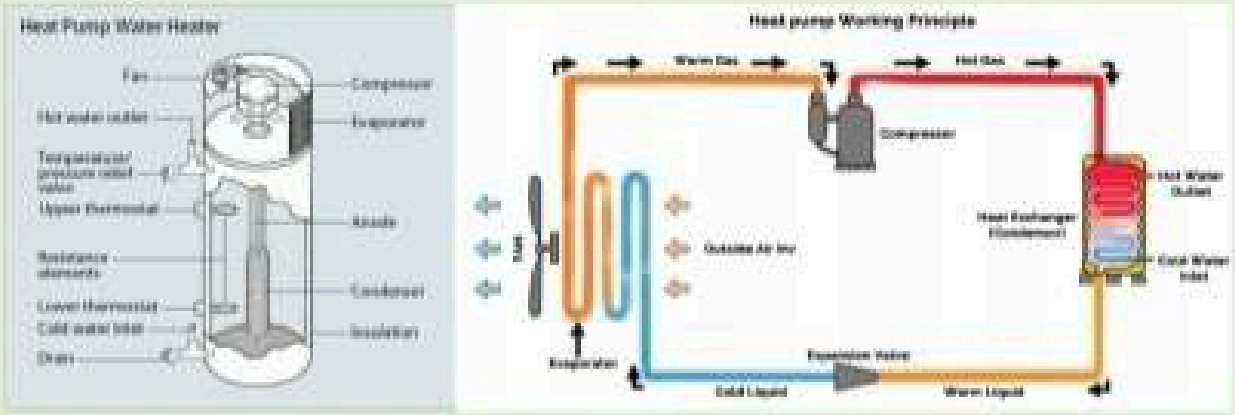


Figure 40 Heat pump based geyser

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:

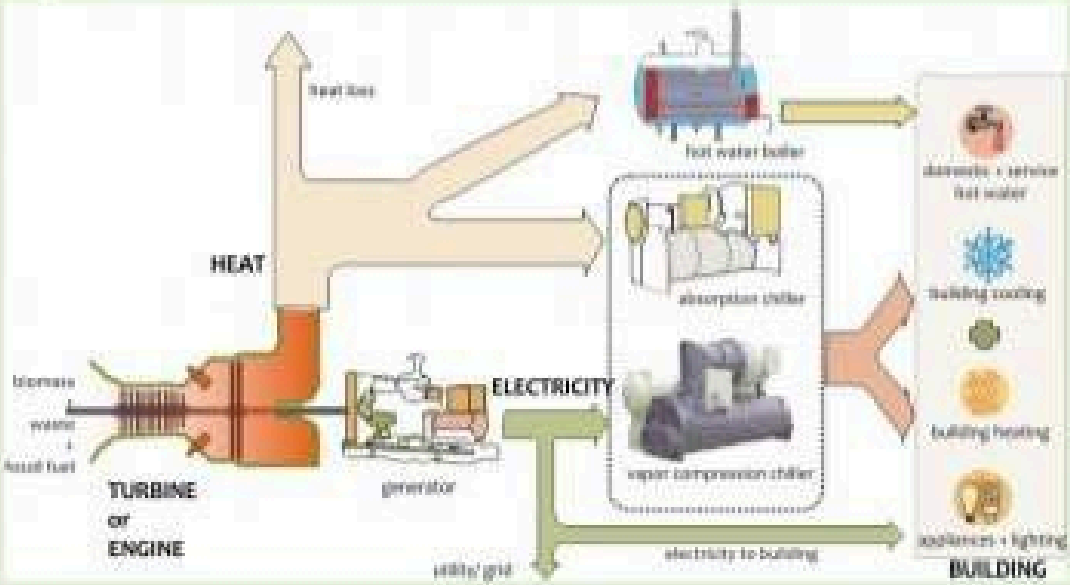


Figure 42 Tri-generation system for buildings

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).

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

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.

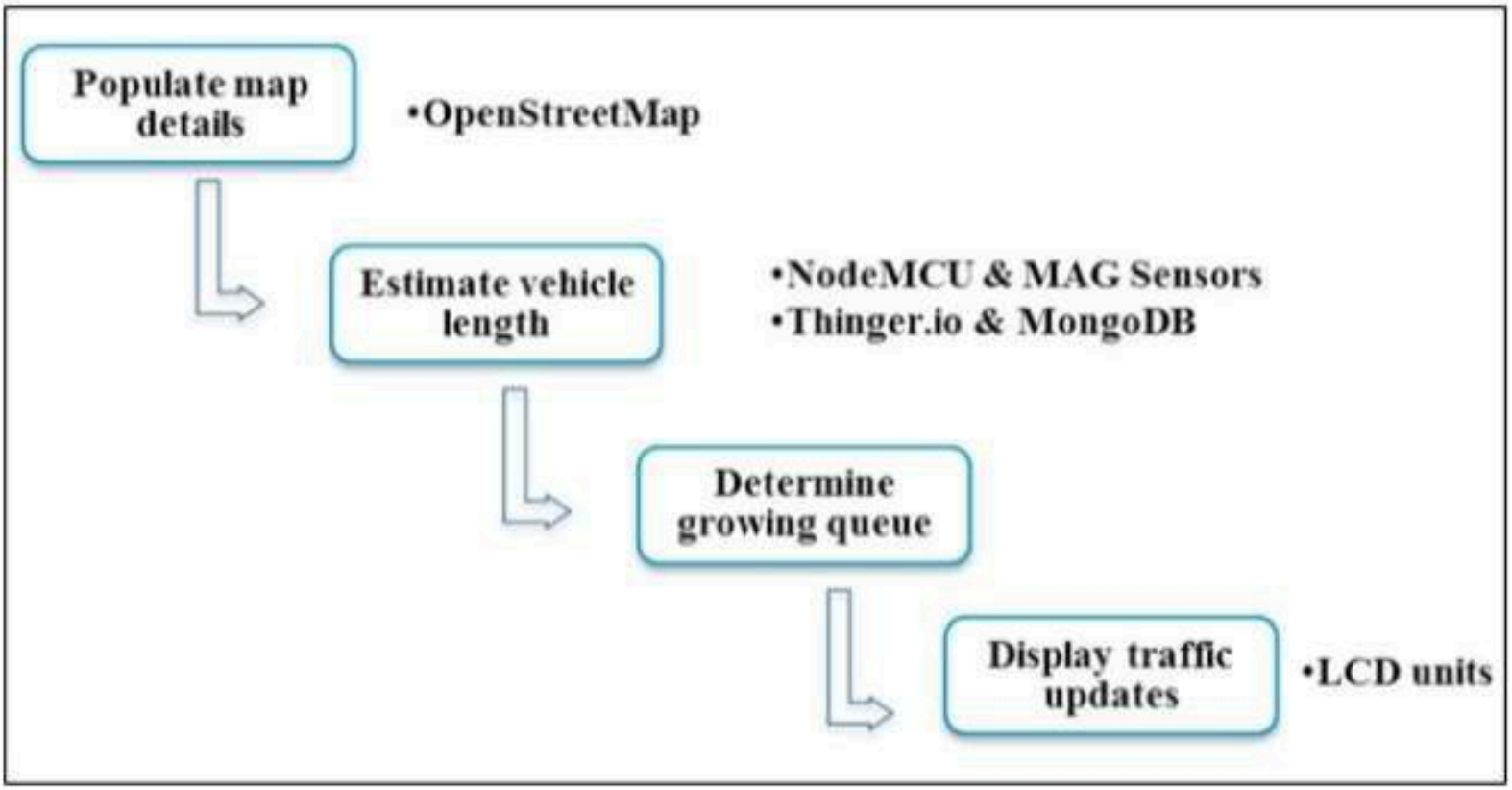
a) Smart external blinds

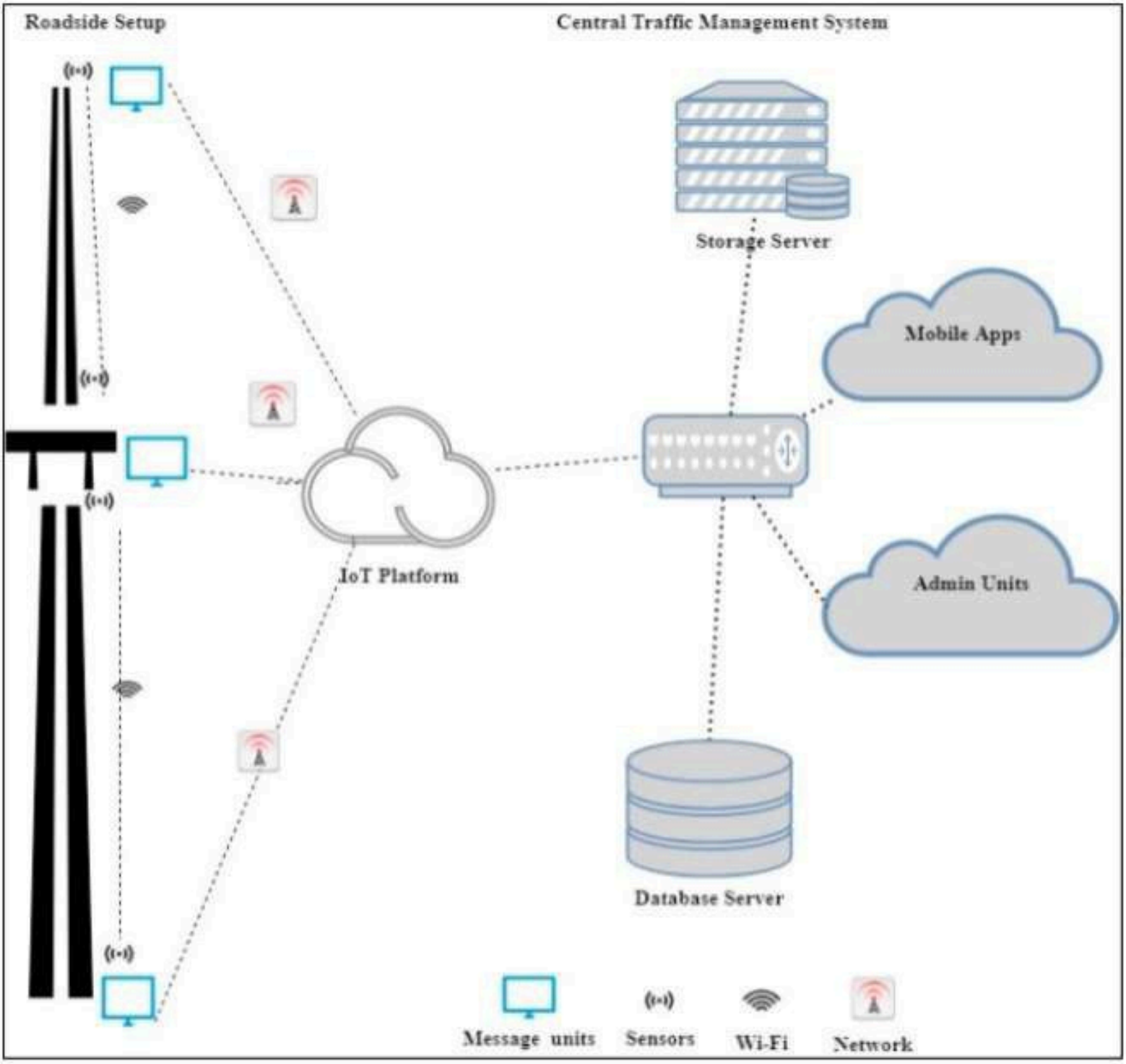
Windows form an important aesthetic and interactive element of a building. Windows are used to access outdoor views and natural ventilation. However, it might not always be possible to keep a window open especially when the solar radiation directly falling on the window and adding up to the heat gains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


Populate map details
•OpenStreetMap
Estimate vehicle length
•NodeMCU & MAG Sensors
•Thinger.io & MongoDB
Determine growing queue
Display traffic updates
•LCD units


Roadside Setup
Central Traffic Management System
Storage Server
Mobile Apps
IoT Platform
Admin Units
Database Server
Message units
Sensors
Wi-Fi
Network

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:

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

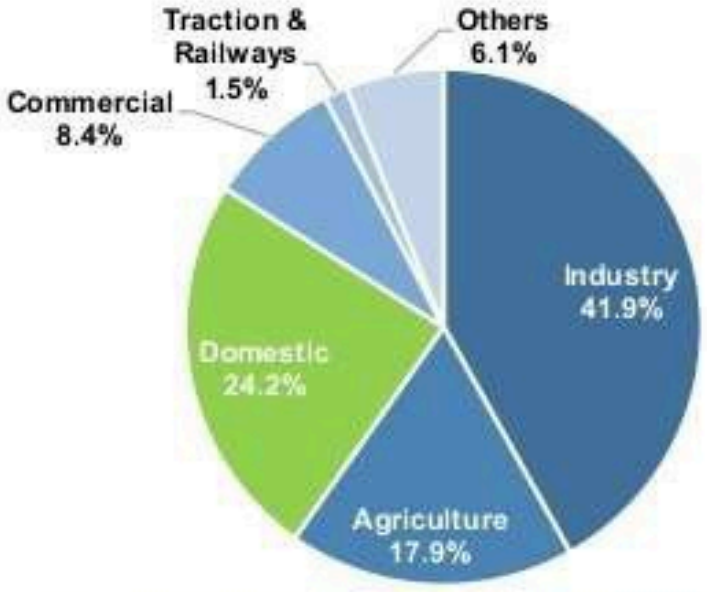
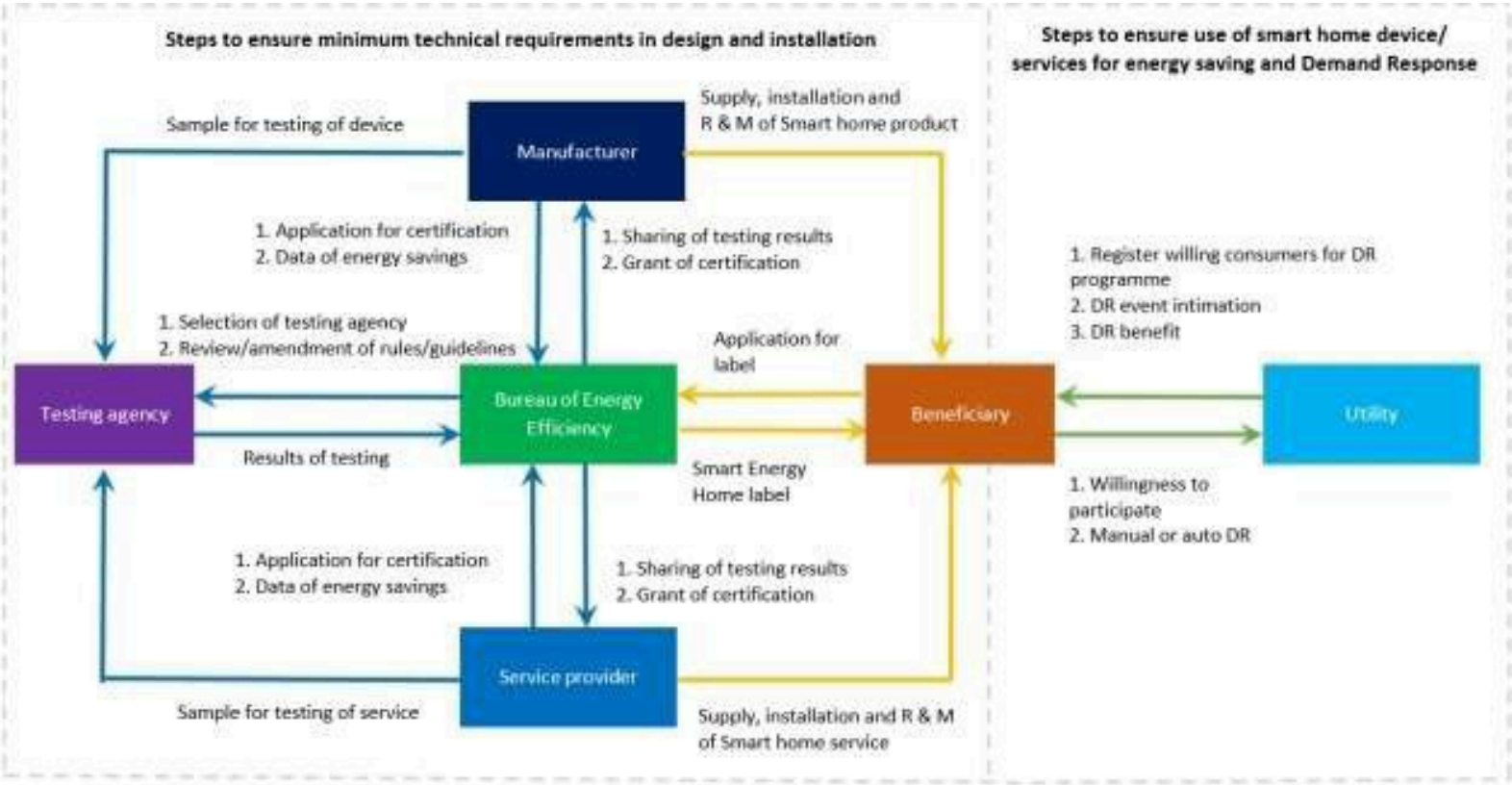


Figure 1 Sector wise electricity consumption in FY 2018-19, Source: Energy Statistics 2020, MOSPI



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

- 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 bad 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:

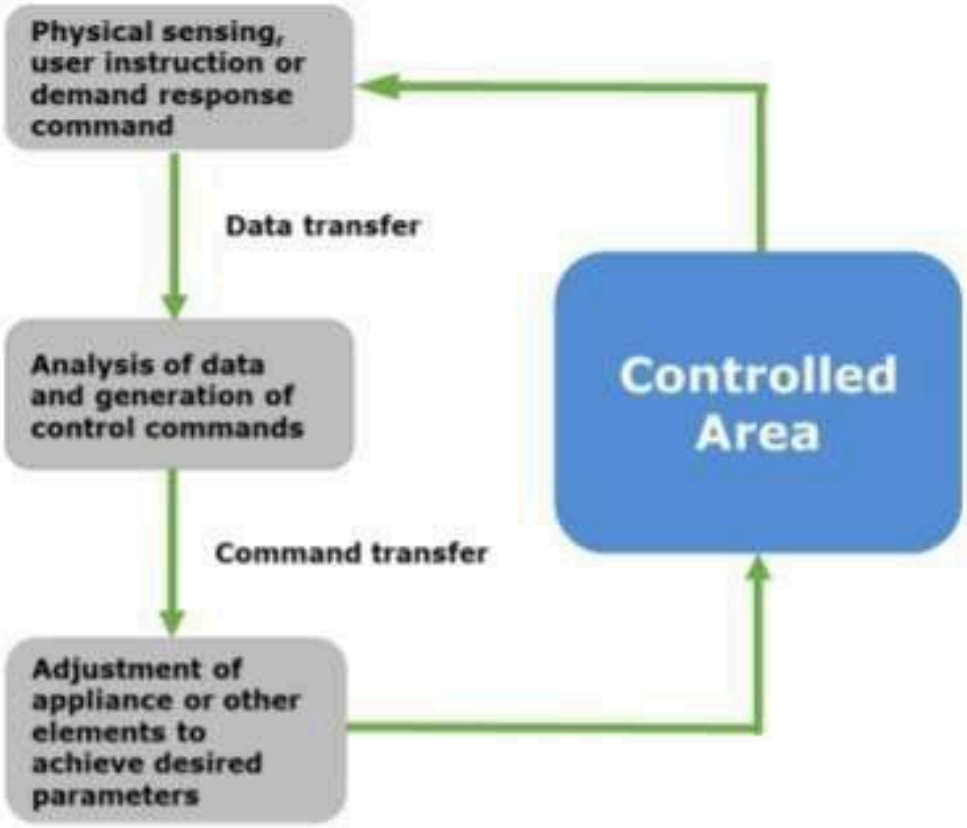


Figure 6 Working of smart home system

- 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].

- **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**

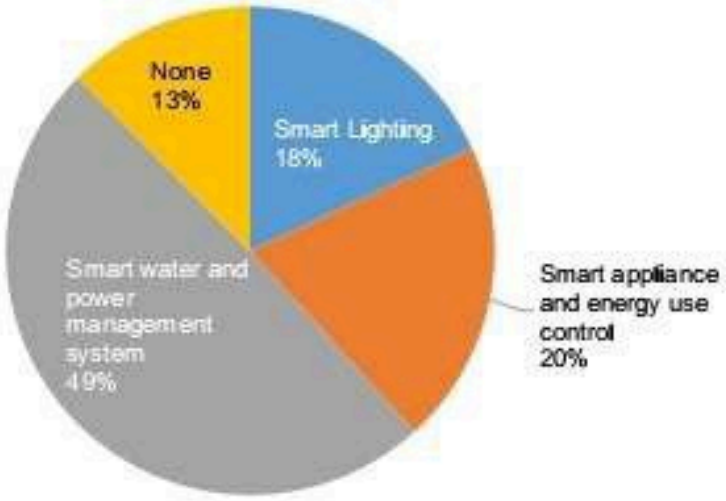
  India is yet to implement data privacy laws and regulations. This is one of the principal concerns to OEMs and service providers as big data has to be collated at a central server to analyse and build AI trends. Home automation command via voice and gestures will be widely accepted as part of the 'Human- 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**

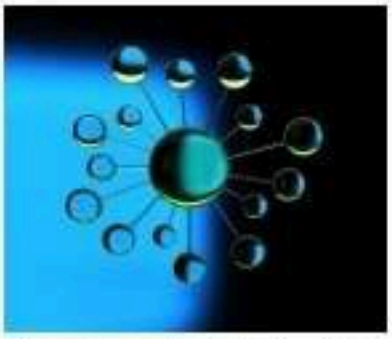
  In India, majority of the homes are constructed by realty developers. In absence of a policy guideline or mandate, this mass housing segment does not target home automation as a pre-sales option. The later (post occupancy) adoption of home automation by a consumer becomes difficult and costly affair, 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:



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.

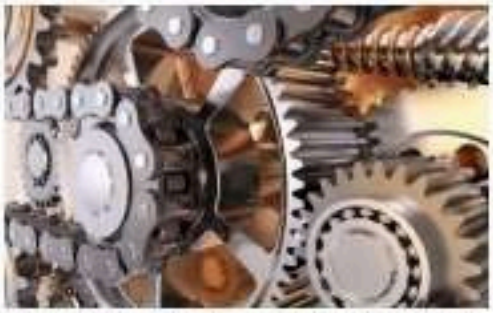
6. Smart home aggregators



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



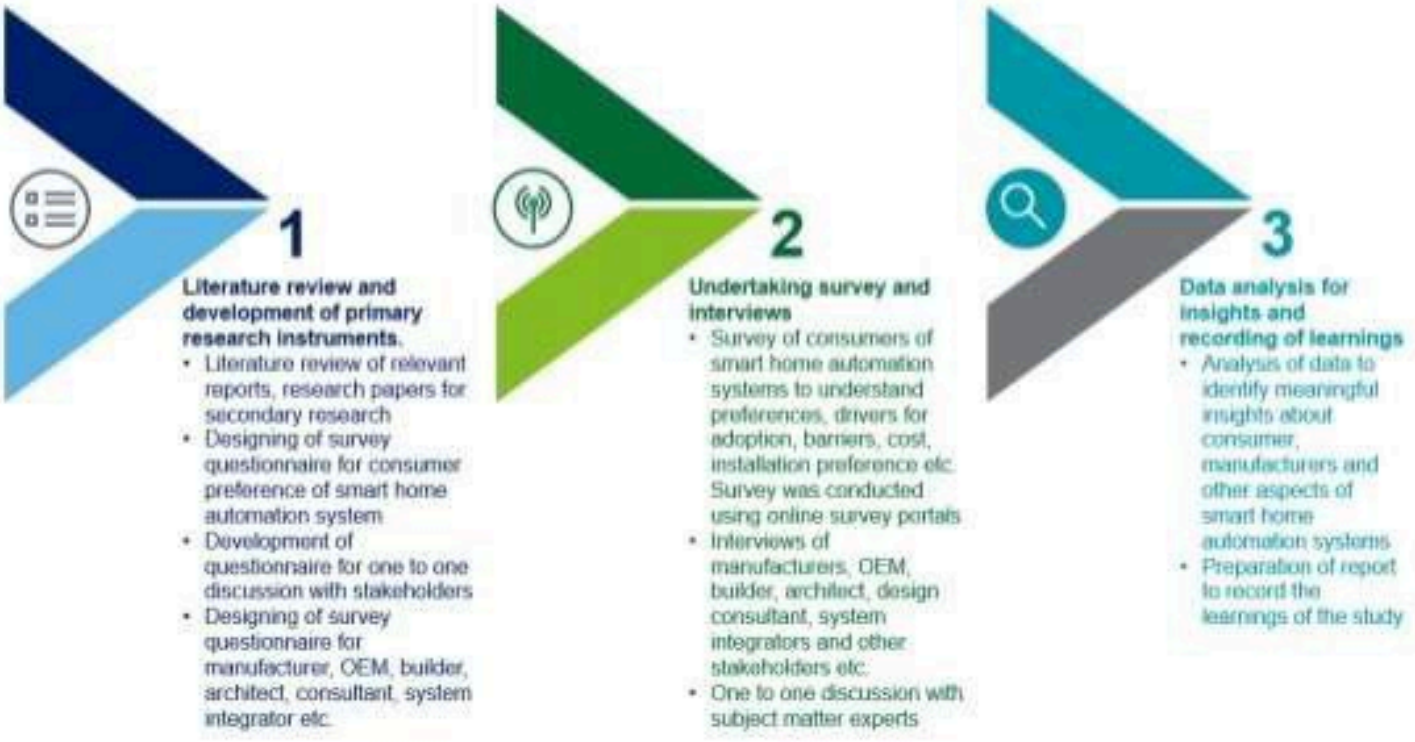
Standardisation and interoperability are vital to ensuring the success and security of IoT solutions in the home automation sector.

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.

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:



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.

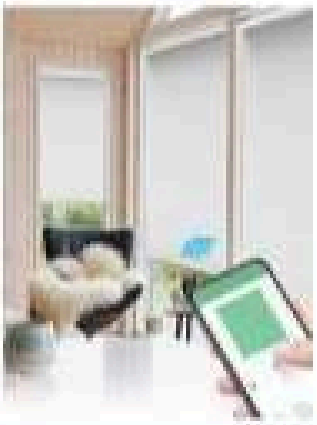


Figure 57 Smart Outdoor Blinds

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) with single glaze, 6 mm clear glass. No overhang was considered in this case. Based on simulation, 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 humidity conditions)

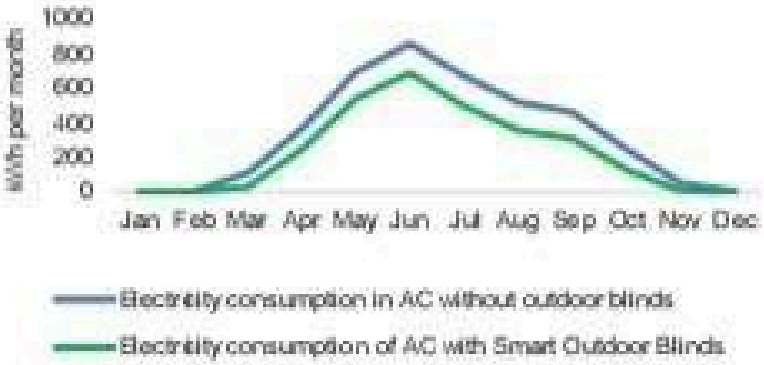


Figure 58 Smart outdoor blinds – simulation results

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 composes 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

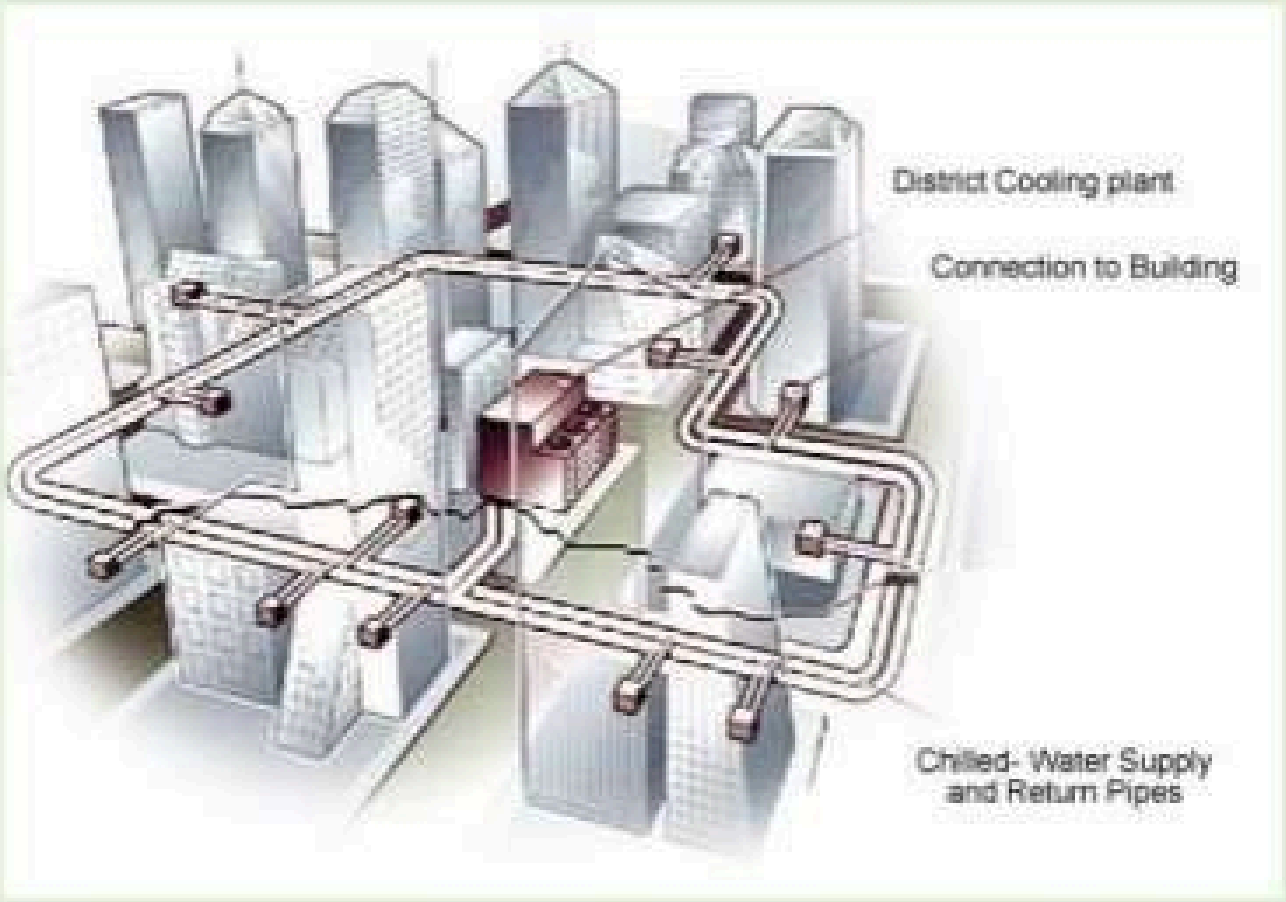


Figure 47 District Cooling System

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_system.html

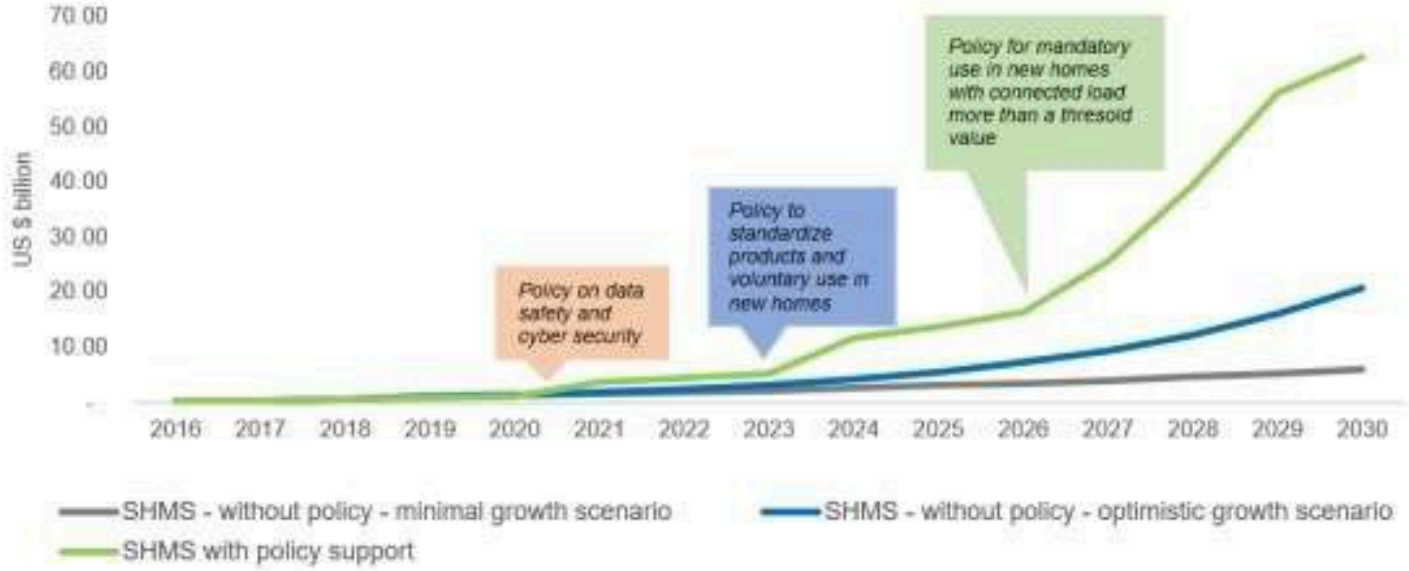


Figure 21 Forecast for smart home market size, with and without policy intervention

Smart home market size – without policy intervention

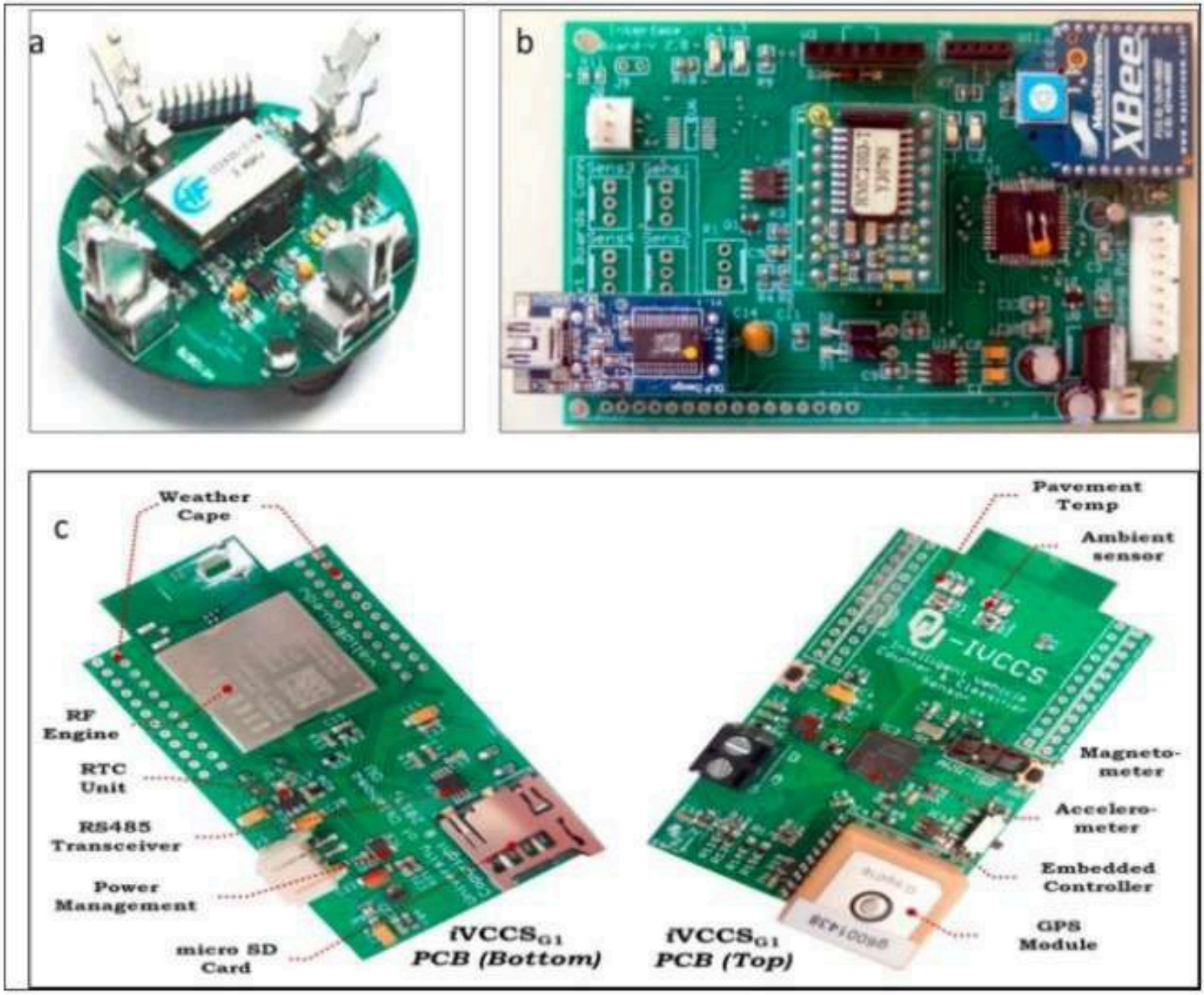
In absence of any major policy interventions, the smart home market is expected to reach US$ 20 billion in optimistic growth scenario and US$ 6 billion in minimal growth scenario.

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.


a
b
XBee
c
Weather Cape
RF Engine
RTC Unit
RS485 Transceiver
Power Management
micro SD Card
iVCCS$_{G1}$ PCB (Bottom)
Pavement Temp
Ambient sensor
Magneto-meter
Accelero-meter
Embedded Controller
GPS Module
iVCCS$_{G1}$ PCB (Top)

PROGRAM

```
# Traffic Management Component
import paho.mqtt.client as mqtt

def on_message(client, userdata, message):
    # Process traffic data and take actions
    pass

client = mqtt.Client()
client.on_message = on_message
client.connect("mqtt_broker_address", 1883)
client.subscribe("traffic_data_topic")
client.loop_start()

# Home Automation Component
import paho.mqtt.client as mqtt

def on_message(client, userdata, message):
    # Control home automation devices based on
the received message
    pass

client = mqtt.Client()
client.on_message = on_message
client.connect("mqtt_broker_address", 1883)
client.subscribe("home_automation_topic")
client.loop_start()
```

Home Automation Component

```
import paho.mqtt.client as mqtt

def on_message(client, userdata, message):
    # Control home automation devices based on the received message
    pass

client = mqtt.Client()
client.on_message = on_message
client.connect("mqtt_broker_address", 1883)
client.subscribe("home_automation_topic")
client.loop_start()
```

THANK

YOU