SHAKTI SUSTAINABLE ENERGY FOUNDATION

A diagnostic study of the energy efficiency of IoT

A technology and energy assessment report

Prepared for Shakti Sustainable Energy Foundation

pwc

ISGF India Smart Grid Forum

January 2018

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An initiative supported by

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support renewable energy, energy efficiency and sustainable transport solutions.

Acknowledgement

Pricewaterhouse Coopers (PwC) and India Smart Grid Forum (ISGF) place on record our sincere gratitude to **Shakti Sustainable Energy Foundation** (SSEF) for entrusting us with the assignment of "**A diagnostic study of the energy efficiency of IoT (Internet of Things)**".

The study was conducted under the guidance and direction of **Mr. Shubhashis Dey, Program Manager, Energy Efficiency** at SSEF. His contribution during the entire course of the project was very valuable and helped the project team to shape the study. We would like to thank **Nandini Sharma** from SSEF for her continuous assistance. Led by **Amit Kumar**, PwC India, the team responsible for execution of the study comprised **Samved Patil**, **Shuboday Ganta** and **Akash Gupta**. The report with the analyses was prepared by Akash Gupta. The work was supervised by **Mr. Kulbhushan Kumar** from PwC India.

We are grateful to **India Smart Grid Forum** (ISGF) for providing notable assistance on the technological aspect of the study. We would like to thank **Mr. Rupendra Bhatnagar**, **Ms. Reena Suri, Mr. Ankush Malhar**, **Mr. Suddhasatta Kundu and Mr. Shobhit Jain** from ISGF for their invaluable contribution to the study.

This study has greatly benefited from the interactions with officials of **Department of Technology** (DoT), **Bureau of Energy Efficiency** (BEE) and **Ministry of Electronics and Information Technology** (Meity) and several equipment manufacturers. We would like to acknowledge the assistance and guidance provided by **Mr. Kishore Narang** (Founder of Narnix Technolabs Pvt. Ltd.). Pricewaterhouse Coopers would also like to acknowledge the contribution of all the stakeholders for participating in the interviews and providing their inputs on energy use data to conduct the analysis to project the energy impact from the expected proliferation of IoT (Internet of Things) devices.

1. Executive Summary

This is an executive summary of the IoT (Internet of Things) diagnostic study conducted for Shakti Sustainable Energy Foundation in 2017. The study was conducted over a 6 month period by the PwC – GRID energy efficiency team along with the partnership of India Smart Grid Forum (ISGF). The Internet of Things (IoT) is a rapidly evolving space in which virtually any smart hardware device—a mobile phone, a pacemaker, a wearable fitness sensor, even a refrigerator—can be connected to the internet to generate and receive data. But for the continuous transfer of data, these devices need to stay active all the time resulting in power consumption.

Hence, the study becomes of utmost importance as it tries to investigate and quantify the energy impact from the expected proliferation of important IoT solutions. The study also attempts to project and map this energy impact to the various communication technologies adopted by the IoT industry to inform policymakers on how the evolution of different IoT communication technologies impacts overall consumption. And, some high-level recommendations to adopt methods to restrict the standby power dissipation have been suggested.

The following 10 IoT solutions were proposed after the extensive deliberation between PwC and ISGF:

- Smart light bulbs
- Smart street lighting systems
- Smart controllers for irrigation pump sets
- Smart sockets
- Smart meters
- Smart air conditioners/thermostats
- Smart geysers
- Smart refrigerators
- Smart televisions
- Home and building automation systems

The report has been segregated into five tasks. Firstly, a brief overview of proposed IoT solutions has been presented along with their standby power data. Available IoT communication technologies have been studied and a technology fit for the proposed IoT solution has been derived. Then the expected proliferation for smart products has been estimated over a period of 14 years i.e. starting from FY 2017-18 till FY 2029-30 considering three different growth rate scenarios while forecasting. The standby power dissipation of proposed IoT solutions has been calculated and their impact on the national energy consumption is assessed based on market forecasts and the standby power values. And finally, IoT policy and regulatory framework has been studied and actions have been provided to ensure adoption of low power communication technologies and to curb the standby power.

The assessment approach centres on stakeholder consultations and desktop research that drew largely on the available information. The product level information is compiled through expert interviews and secondary information shared by the suppliers/manufacturers of the product as well as publicly available sources. This mass of information is then used to develop the proliferation and energy impact projections on a year-by-year basis over a 14-year horizon. Drivers and restraints in the global, regional and national markets and submarkets have also been taken into consideration while preparing forecasting projections.

1.1. Key findings of the report

a. Standby power data

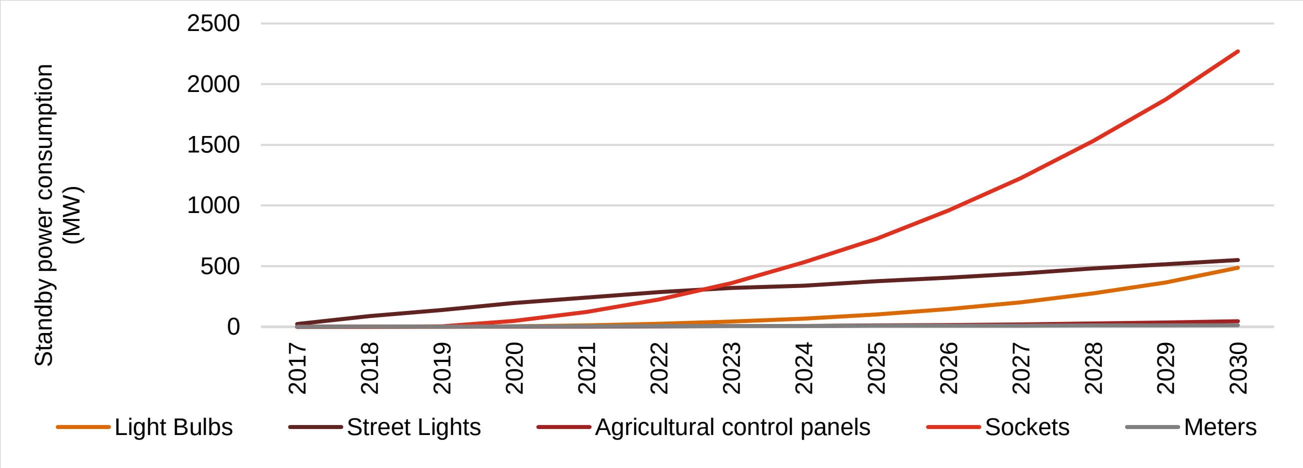
The standby power of most of the products covered lie in the ranges of less than 1 Watt except the home and building automation systems. The illustrative table has been presented below to depict the standby power values of the covered products.

Proposed IoT solution	Product	Gateway	Communication technology	Standby power in Watts
Smart bulbs	Bulb using Wi-Fi and ZigBee	Yes	Wi-Fi and ZigBee	0.4
	Bulb using Wi-Fi	No	Wi-Fi	0.5
	Bulb using Bluetooth	No	Bluetooth	1
Smart street lights	GSM/GPRS based Group Controller	Feeder Panel	GSM/GPRS	5
	GSM/GPRS based Individual lamp Controller	Gateway	GSM/GPRS	6
	LR-WPAN and Wi-Fi/2G/3G based Individual lamp controller	Gateway	RF mesh	0.65
Smart agricultural control panels	GSM based Mobile Starters	No	Quad Band GSM	1.5
Smart sockets	Wi-Fi based socket	No	Wi-Fi	3
	GSM based socket	No	GSM	1.76
Smart meters	Wi-Fi based meter	Router	Wi-Fi	0.00045
	LoRa based meter	Gateway	LoRa	0.00924
	RF based meter	No	RF	0.025
Smart ACs	Wi-Fi based AC	No	Wi-Fi, RF	0.1
	Wi-Fi AC + App	No	Wi-Fi	0.001
Smart geyser	Wi-Fi based smart geyser	Yes	Wi-Fi, IR remote technology	0.001
Smart refrigerator	RF-based refrigerator	No	RF frequency	0.001
Smart TV	Wi-Fi based TV	No	Wi-Fi	0.001
Home and Building Automation	KNX based home automation system	Yes	KNX	1
	ZigBee/Wi-Fi based home automation system	Yes	ZigBee/Wi-Fi	10

b. Energy impact of the standby power by IoT products

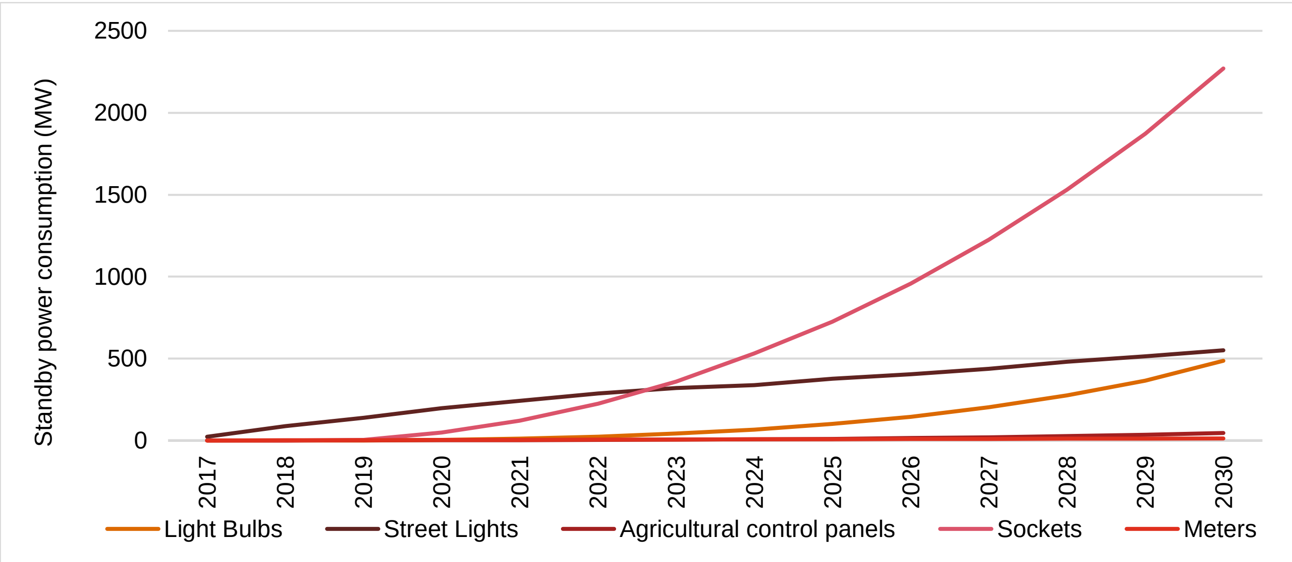
Scenario A considers that products covered employ the communication technology with maximum standby power whereas **Scenario B** considers that the products covered employ the communication technology with minimum standby power among the studied communication technologies.

Scenario A



- The standby-power dissipation of the IoT devices considered in the report is growing by 74.7% from 2017 till 2030 in this scenario.
- Of the IoT solutions studied in the report, total standby power dissipation by 2030 comes out to be 3375.5 MW. **Hence, the additional load increment due to standby power will be 3.37 GW which forms 1% of the currently installed capacity of India.**
- **The total impact on the energy consumption comes out to be 27.15 TWh for FY 2029-2030** (assuming all the proposed IoT solutions stay in operation for 24 hours a day except street lights that remain ON for 12 hours in a day).
- The most significant contributors to the standby power dissipation till 2030 in India are expected to be smart sockets, smart light bulbs and smart street lights.
- Smart sockets consume 2.27 GW which forms 67% of the total standby power dissipation.

Scenario B



- The network related standby-power dissipation of the IoT devices considered in the report is growing by 64.7% in this scenario.
- Of the IoT solutions studied in the report, total standby power dissipation by 2030 comes out to be 1487.4 MW. **Hence, the additional load increment due to standby power will be 1.48 GW which forms 0.45% of the currently installed capacity of India.**

- **The total impact on the energy consumption comes out to be 12.76 TWh for FY 2029-2030** (assuming all the proposed IoT solutions stay in operation for 24 hours a day except street lights that remain ON for 12 hours in a day).
- The most significant contributors to the standby power dissipation till 2030 in India are expected to be smart light bulbs, smart meters and smart sockets where smart sockets contribute around 90% to the total standby power dissipation.

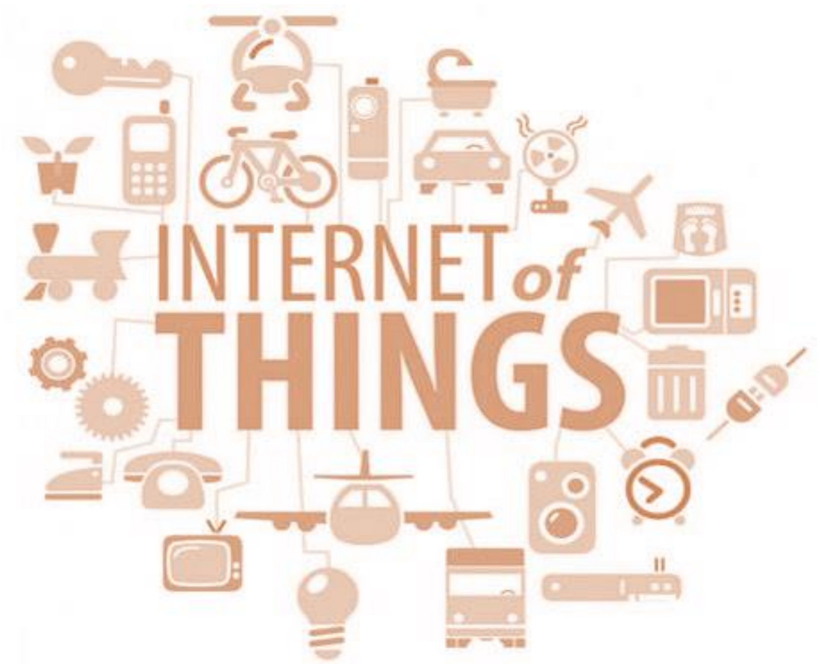
c. Recommendations to reduce the standby power consumption

- To introduce One-Watt policy
- To encourage low-power communication technologies wherever appropriate, and
- To extend the scope of existing green building codes and rating systems to include advanced IoT systems

2. Introduction

The Internet of things, popularly known as IoT, is an emerging disruptive technology that transforms the way physical objects/assets operate and add value in any industry vertical. India has become a rapidly growing hub for IoT solutions. NASSCOM estimates that the Indian market for IoT is likely to touch 15 billion USD in the next five years[1]. On the policy front, the Government of India's 'Smart Cities Mission' and the 'Digital India Mission' are expected to provide the required impetus for the development of the IoT industry in the country. The leading industry verticals/markets demanding IoT solutions are energy, manufacturing, healthcare, transportation, logistics, agriculture, city infrastructure, homes/buildings, and lighting and consumer appliances.

Figure 1: IoT applications in various sectors



Source: http://www.china-code.com/upload/201608/09/201608091658247798.jpg

The Indian IoT industry is at a crossroads today. The 'National M2M Roadmap', published by the Department of Telecommunications and the 'Draft Policy Framework on IoT', notified by the Ministry of Electronics & Information Technology (MeitY), has placed special emphasis on developing and adopting globally established and interoperable IoT standards in the country. The standards for energy consumption are one of the key aspects envisaged in this policy framework. By adopting such standards, the policy aims to address the possible increase in energy consumption from the rapid proliferation of IoT objects that are expected to be reachable by other devices and consumers at all times. The sensors, actuators, gateways, communication modules and other network-related subcomponents of IoT solutions remain active most of the time to enable a seamless exchange of information, access and control. The rapid proliferation of such objects raises concerns regarding excessive standby power. In this context, the policy aims to create a National Expert Committee on Communication Technologies, among many other aspects, to promote ultra-low power chipsets on IoT devices. The policy also aims to provide incentives directed to support companies in the IoT domain to create low-power devices, among many other solutions.

[1] Retrieved from: http://www.livemint.com/Industry/Eod6fNbGYfuDQUI31JRrgN/Indian-IoT-market-to-touch-15-billion-by-2020-Nasscom.html

2.1. Objective of the report

The overall objective of this study is to stimulate policy dialogue among key stakeholders for guiding the evolution of the IoT industry and its adoption of low-power communication technologies, minimise the risk of excess energy footprint and also gauge the industry's readiness for embracing standby power standards. Through this study, the aim is to:

- Bridge the information gap regarding energy management features and characteristics of important IoT solutions/products available in the market. This is expected to help stakeholders advance the objective of creating awareness among energy end users/consumers and institutions about how they can realise value in terms of energy and cost savings from IoT solutions.
- Investigate and quantify the energy impact from the expected proliferation of important IoT solutions.
- Project and map this energy impact to the various communication technologies adopted by the IoT industry to inform policymakers on how the evolution of different IoT communication technologies impacts overall consumption.
- Develop high-level recommendations to adopt methods to restrict standby power dissipation.

2.2. Structure of the report

In this regard, the study has been divided into five tasks (see graphic below) in the logical order of their execution:

Task 1 – Overview of proposed IoT solutions along with their standby power values

Task 2 – Examination of the IoT communication technology landscape in India

Task 3 – Scenario-based projection of expected proliferation of IoT solutions in the Indian markets

Task 4 – Projecting the energy impact from the expected proliferation of IoT solutions and energy-efficiency potential from the adoption of low-power communication technologies and IoT devices

Task 5 – Policy and regulatory IoT framework and high-level recommendations to adopt low-power communication technologies and restrict standby power

2.3. Contents of the report

In chapter 2 of this report, a brief overview of proposed IoT solutions has been presented along with their standby power data.

In chapter 3, available communication technologies have been studied and a technology fit for the proposed IoT solution has been derived. It also covers the upcoming technologies and their relevance in the Indian IoT market.

In chapter 4, the expected proliferation of smart products has been estimated over a period of 14 years, i.e. starting from FY 2017–18 till FY 2029–30. To have a more insightful approach covering a range of possibilities, three different growth rate scenarios have been considered while forecasting.

In chapter 5, the standby power dissipation of proposed IoT solutions has been calculated and their impact on the national energy consumption is assessed based on market forecasts and the standby power values presented in chapter 3. This chapter also attempts to estimate the energy efficiency potential from the adoption of low-power communication technologies and smart devices.

In the last chapter, the IoT policy and regulatory framework have been studied and actions have been provided to promote the adoption of low-power communication technologies and to curb standby power.

2.4. Scope of work

The project focuses upon:

- Emerging IoT application areas for which the future growth potential seems vast
- Standby power dissipation of these IoT solutions
- Mains-connected devices

The following topics were kept out of scope:

- Devices whose primary function is communication or data transfer, such as cell phones and computers
- IoT solutions in manufacturing, healthcare, transportation, and logistics; these devices were not included on account of limited publicly available information and perceived complexity
- Battery or self-powered devices or devices powered by on-board generators
- Big data and cloud computing
- Privacy, security and interoperability issues

2.5. Methodology

This study was conducted over a six-month period in 2017 by PwC's GRID – Energy Efficiency team in partnership with the India Smart Grid Forum (ISGF). The assessment approach centres on stakeholder consultations and desktop research that drew largely on available information.

Product-level information was compiled through expert interviews and secondary information shared by the suppliers/manufacturers of the product as well as publicly available sources. This mass of information was then used to develop the proliferation and energy impact projections on a year-by-year basis over a 14-year horizon. Drivers and restraints in the global, regional and national markets and sub-markets have also been taken into consideration while preparing forecasting projections.

The entire body of secondary and primary research was then blended together to produce a cohesive research report which, due to its breadth of sources, produces an accurate, thorough and analytical overview of the IoT sector in question.

Note:

Physical tests were not conducted for determining the energy consumption of the IoT products.

2.6. Sources of information

Sources of information used for preparing this report include:

- Public information as well as other reports which are available for public review
- PwC's internal database (EMIS, Factiva, Autofacts, Avention, Transform, etc.)
- Subscription-based information
- Online research, including third-party references
- Trade associations, directories and publications
- One-on-one meetings and telephone interviews with stakeholders
- Various private industry sources

3. Task I – Overview of product profiles and standby power data

This chapter details the contextual background and the current market of IoT solutions, along with their standby power values.

3.1. What is an IoT device?

For the purpose of this project, an IoT device (or a smart device) has been defined as having the following characteristics:

- It is a physical object that is part of everybody's daily life and whose primary function is not directly related to information and communication technology, e.g. a refrigerator.
- The objects are identifiable, addressable and can be integrated into communication networks.
- The objects are capable of data capture (internal/external), data processing and may be able to act, i.e. a smart meter sending data to the control panel or master server on a timely basis.
- Networks consist of interoperable information and communication infrastructure and software, e.g. a user controlling the intensity of a light bulb with his mobile via Bluetooth forms communication infrastructure.
    - IoT objects can be connected via any of the following networks:
    - Indoor electrical wiring
    - Wired networks (IEEE 802.3 Ethernet)
    - WPANs (Bluetooth, Dash7, 6Lo-WPAN, ZigBee, NFC)
    - Wi-Fi (IEEE 802.11)
    - Programmable logic controller (PLC)
    - PSTN/DSL/ADSL
    - Low-power wide-area network (LPWAN) (LoRa)
    - 2G/3G/4G
    - Satellites

Notes and assumptions:

- Devices powered by batteries (remote-controlled or devices acting as a remote control, i.e. a smartphone), on-board generators (i.e. for automotive applications) and energy harvesting have been excluded from the investigations.
- IoT applications requiring battery-powered edge devices are a major driver for low-power communication standards specifically developed for IoT. But since the consumer would not accept low battery lifetimes, major improvements have already been made in the past years. Smartphones and such devices typically make use of Wi-Fi or Bluetooth to connect to a WLAN or to other devices such as wearable fitness trackers. And to ensure acceptable battery lifetimes, these existing standards have therefore been extended considerably with power-saving features. Hence, the expected future contribution of mains-connected devices to the worldwide annual energy consumption is significant and should be optimised.

3.2. What is standby power?

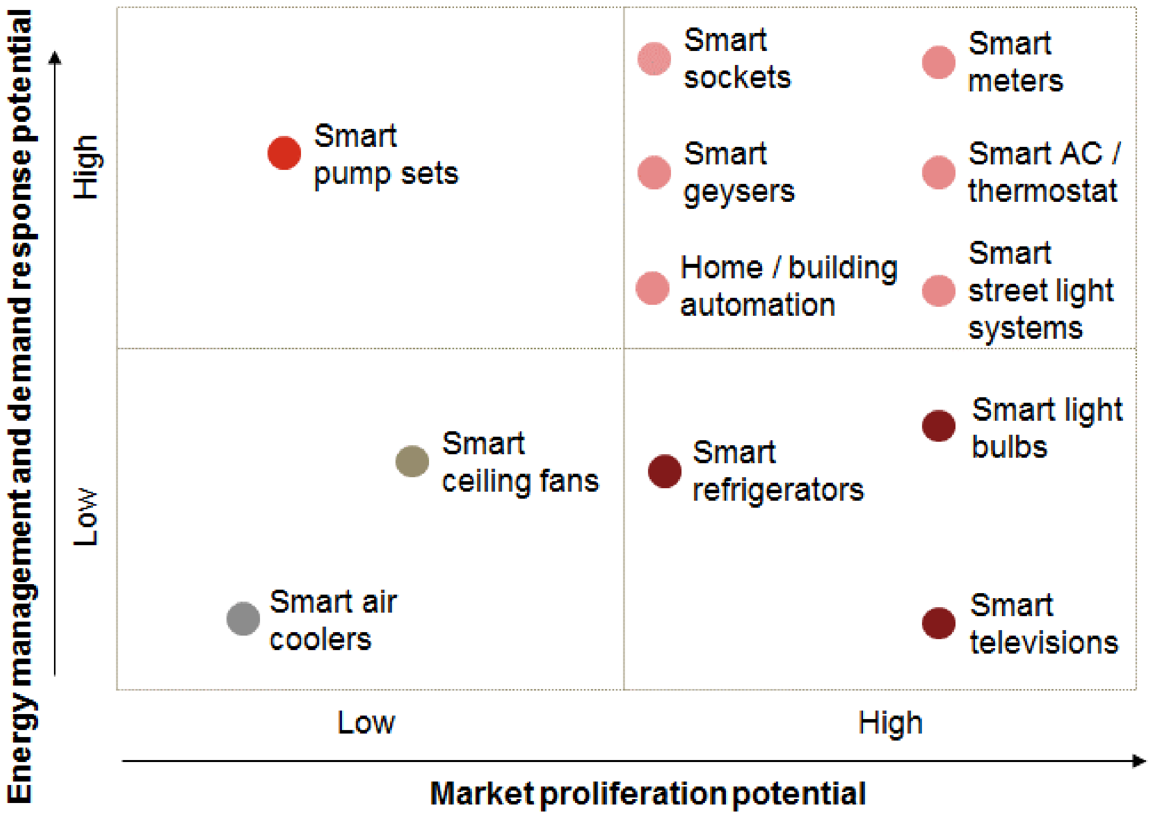
Standby power is also known as leaking electricity, vampire power or phantom power. It refers to the energy drawn by an electronic or electrical device when it's not in use or when the device is in idle mode. That power is drawn by internal or external power supplies, remote control receivers, text or light displays, circuits energised when the device is plugged in even when switched off, etc.

For this report, the scope of the term 'standby power' has been limited to the power drawn by IoT components such as gateways, routers, sensors and actuators that are installed within a mains-connected device.

3.3. IoT solutions covered in the report

Various emerging IoT solutions that fit the characteristics of IoT devices have been mapped according to their perceived[2] market proliferation and energy management potential in the key markets, such as energy, agriculture, municipal infrastructure, homes/buildings, and lighting and consumer appliances.

Figure 2: Mapping of IoT solutions against their perceived market proliferation and energy management potential



Considering the above analysis, the following 10 IoT solutions emerge as important both in terms of energy footprint and energy management potential:

- Smart light bulbs
- Smart street lighting systems
- Smart controllers for irrigation pump sets

[2] Perception of market proliferation has been captured through published and authentic market reports, PwC and ISGF internal database and one on one meetings or telephone interviews with stakeholders

- Smart sockets
- Smart meters
- Smart ACs/thermostats
- Smart geysers
- Smart refrigerators
- Smart TVs
- Home and building automation systems

The above-mentioned IoT solutions are expected to proliferate through a combination of market and policy-driven factors. In some cases, the government has created an ecosystem for such proliferation. In the energy markets, 'smart metering' is clearly the most popular IoT solution, whose deployment is at the heart of the electricity reforms and smart grid vision of the Government of India. In the next two to three years, 35 million smart meters are expected to be rolled out under the Ujwal DISCOM Assurance Yojana (UDAY) scheme. The overall market size resulting from the universal penetration of smart meters in India is approximately 250 million and growing. Smart metering is also an integral part of the many emerging IoT solutions in the context of energy management and the crux of realising the demand response potential for electric utilities in the country.

In the municipal infrastructure markets, smart street lighting systems have been gaining momentum as the most popular IoT solution in recent times to optimise usage and improve operational performance. Under the 'Smart Cities Mission', automation, smart meters and smart public lighting systems are important solutions envisaged to meet the developmental goals of the urban economy. The smart socket/plug is another popular IoT solution with tremendous potential for energy monitoring and management.

In the agriculture pumping segment, smart control panels present a tremendous opportunity for energy monitoring and management in a market that is predominantly unmetered.

In the lighting market, the smart light bulb is the most popular and emerging IoT solution with tremendous potential for market proliferation, although its energy management potential is still uncertain.

In the consumer appliances market, full-fledged IoT solutions are yet to be launched in different end use applications. A recent study by Prayas has indicated that apart from lighting, ACs, fans, air coolers, refrigerators, geysers, and TVs are the energy-guzzling appliances in Indian households[3]. However, not all of these appliances are important in the context of their market proliferation and energy management/demand response potential. Smart ACs and geysers assume importance given their high-energy consumption and intermittence in usage. On the other hand, smart refrigerators and TVs could be considered for their high-market proliferation potential even though their energy management potential is uncertain.

3.4. Communication technologies employed

Several communication technologies are available today. This overview will provide a brief idea of communication technologies being employed in specific application areas and will also help in better understanding the criteria under which products have been selected for each IoT solution.

Some commonly used communication technologies are Wi-Fi, ZigBee, low-rate wireless personal area networks (LR-WPAN) such as low-power RF mesh, Bluetooth, LoRa, Ethernet, and cellular technology. Most of the products selected operate within these communication technologies.

[3] Lights, ACs, fans, air-coolers, refrigerators, televisions and water heaters account for about 90% of the total electricity consumption in Indian households. Source: Prayas (Energy Group), Residential Electricity Consumption in India: What do we know? December 2016

Table 1: Overview of communication technologies

Technology/protocol	Backhaul/WAN and backbone	Last mile/NAN/FAN	Home area network (HAN)
Wireless	Cellular, satellite, LPWA, long wave radio	RF mesh, ZigBee, Wi-Fi	RF mesh 6LoWPAN, LoRa, ZigBee, Wi-Fi, Bluetooth, Z-Wave, NFC, LoRa
Wired	Optical fibre, Ethernet, PLC, DSL	PLC, Ethernet, serial interfaces, DSL	PLC, Ethernet, serial interfaces

3.5. Product profiles

Products under each IoT solution have been segregated based on the communication technology employed, which makes each product suitable for a specific application area and results in varying standby power. All the present communication technologies available for a product have been taken into consideration and the respective standby power values have been provided in the following sections.

3.5.1. Smart light bulbs

The lighting industry leaders claim that smart light bulbs will become one of the largest IoT devices in the next 5 to 10 years. The next generation of lighting that people will adopt is widely expected to be intelligent and smart[4]. Smart light bulbs available in the market today adopt LED light sources and varied physical configurations, communication technologies and architecture to transform the general interior space lighting experience. Wi-Fi, Bluetooth and ZigBee are the most popular communication technologies adopted by the smart light bulb industry. The gradual reduction in prices of LED components, besides factors such as low maintenance costs and low power, are proving to be the main drivers for the growth of the LED light sources within the smart lighting market.

The global smart lighting market size, in terms of value, is expected to reach 19.47 billion USD by 2022 at a compound annual growth rate (CAGR) of 27.1%; and in terms of volume, the market size is expected to reach 1.27 billion units by 2022 at a CAGR of 71.3% during the forecast period. The market in the Asia-Pacific (APAC) region is expected to grow at the highest rate between 2016 and 2022[5].

In India, the volume of smart light bulbs sold is currently negligible when compared to overall LED lamp sales. But the industry has acknowledged that smart light bulb sales are growing rapidly. The growing consumer demand for convenience, home automation and energy efficiency are expected to be the major factors driving the market. The high upfront costs of smart light bulbs and lack of affordable and effective communication infrastructure will remain the largest barriers to wider adoption.

The current generation of smart light bulbs allow colour adjustment, remote control, monitoring and dimming via smartphones, and can be integrated with popular home automation platforms. The next generation products are expected to feature speakers (for playing music), sensors (for smart home applications – occupancy and temperature), and cameras (for security).

[4] Retrieved from http://economictimes.indiatimes.com/tech/internet/smart-lights-to-become-largest-iot-devices-in-next-5-10-years/articleshow/57789646.cms
[5] Smart lighting market by product type, communication technology software & service, application, and geography – Global Forecast to 2022, MarketsandMarkets report

a. Standby power data for smart bulbs

This section compares the communication technologies employed by different smart light bulbs available in the Indian market and their standby power as claimed by the manufacturers/vendors.

Table 2: Communication technology along with standby power data

Product	Gateway	Communication technology	Power drawn by meter in Watts	Standby power of single smart light bulb/gateway in Watts
Bulb using Wi-Fi and ZigBee	Yes	Wi-Fi and ZigBee	1.5	**0.4**
Bulb using Wi-Fi	No	Wi-Fi	-	**0.5**
Bulb using Bluetooth	No	Bluetooth	0.0	**1.0**

3.5.2. Smart street lights

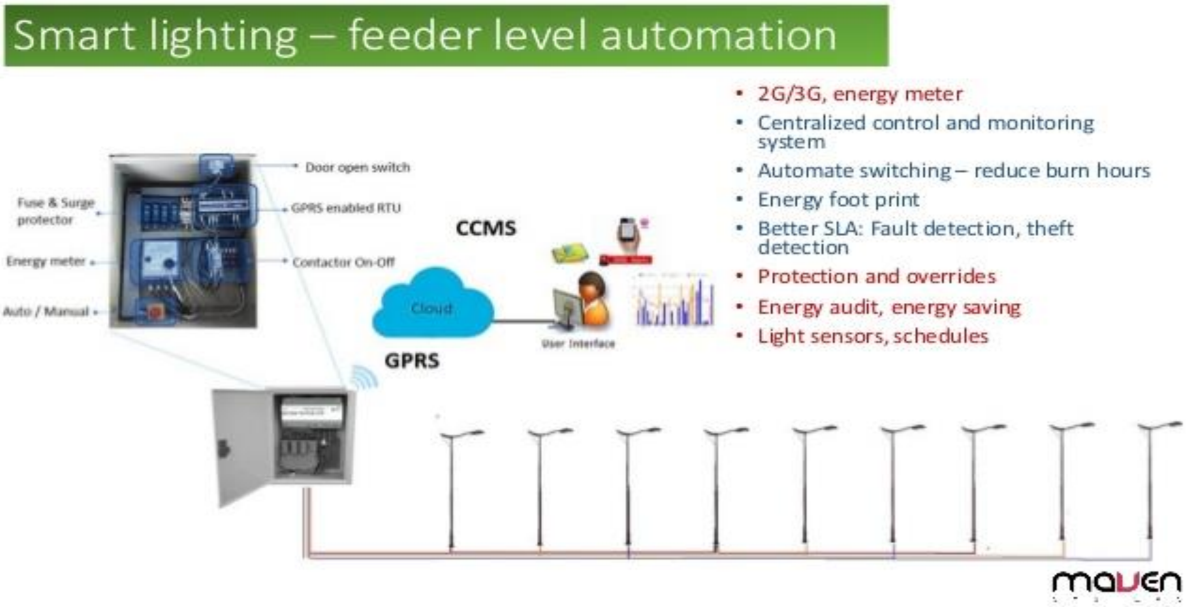
The street lighting market in India is undergoing transformation at an unprecedented scale. There are over 26 lakh LED street lights currently installed under the government's the 'Street Light National Programme' (SLNP), which has set a target for replacing over 3.5 crore conventional street lights across the country. The SLNP programme is further promoting centralised control and monitoring systems (CCMS) as an important solution to improve operational efficiency, monitor and realise savings in the operation and maintenance of LED street lighting infrastructure by municipalities. Through the Energy Efficiency Services Limited (EESL), the government has placed orders to purchase CCMSs worth over 150 crore INR for pan-India installation[6]. Robust solutions are available in the market that also work with conventional lighting systems and the current infrastructure without needing major overhaul.

Remote control and centralised monitoring is one of the key features enabled by CCMS. Important data such as functional status of street light fixtures, fault detection, power drawn and voltage is made available at the click of a button. The solution also allows operators to schedule street lights according to the time of day. Some advanced systems come with daylight and motion sensors to switch on and off lights, increase/decrease luminosity (dimming) based on traffic intensity, and account for changing sunrise and sunset timings throughout the year. Robust wireless communication technologies and architecture are employed to avoid extra wiring, digging and re-paving while enabling the above-mentioned features. The latest trend is to install noise sensors and pollution sensors on the street light poles (cobra heads) which will leverage the same communication bandwidth to transmit the data to the control centres for monitoring noise and air pollution.

There are broadly two types of CCMS configurations available in the market based on the degree of control and monitoring required for the operators. One type allows feeder- or phase-level control and the other type allows the control of individual poles. For systems with feeder-level control, CCMS panels along with sensors (optional) are typically installed at feeder switching points and integrated with energy meters and gateway equipment (optional). While the solution controls the three phases individually, it would not be able to control lights individually. As a result, pinpointing faulty equipment wouldn't be possible with such a solution. On the other hand, the solution would cost less than the alternative. For systems with individual light control, each streetlight will have a CCMS circuit board along with sensors (optional) installed to control the light and transmit all data wirelessly. In order to successfully control the light, the CCMS circuit must be integrated with the LED driver. For the high range of data transmission, the chip must use a far-reach technology and suitable communication protocol to maintain robust connectivity. A gateway or local data concentrators may be needed for certain architecture to collect data from individual lights, communicate the data to head-end systems (HES) or upload the data to the Internet, and also enable control. The solution would be able to pinpoint faulty light and monitor critical information by individual light. However, the solution costs more than phase-wise control.

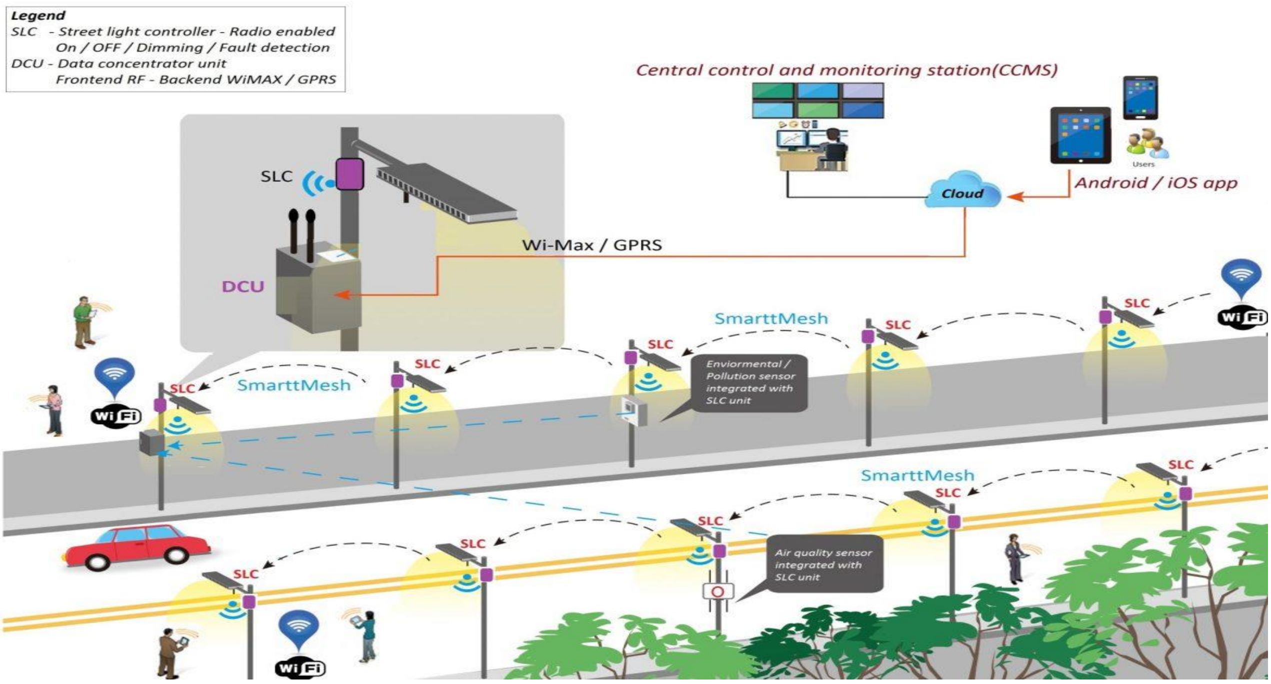
[6] https://eeslindia.org/writereaddata/636239830960312500Procurement%20Data%20of%20EESL%20(1st%20Jan%202017%20-%2031st%20Jan%202017).PDF

Figure 3: CCMS solution with feeder-level control architecture



Source: https://image.slidesharecdn.com/anuragambedkarmoschip-170317025625/95/iot-solutions-for-businesses-20-638.jpg?cb=1489744927

Figure 4: CCMS solution with individual control architecture



Source: https://i1.wp.com/analyticsindiamag.com/wp-content/uploads/2016/04/Architecture-of-the-solution.jpg?resize=1170%2C872

a. Standby power data for smart street lights

The following section compares the communication technologies employed by different smart street lights available in the Indian market and their standby power, as claimed by the manufacturers/vendors. **For smart street lights, router/gateways and the equipment itself have been taken as one system and standby power for the whole system has been considered.**

Table 3: Communication technology along with standby power data

Product	Gateway/ feeder panel	Communi-cation technology	Standby power of gateway / feeder panel in Watts	Standby power of pole-mounted controller in Watts	Net standby power of installed IoT system in Watts
GSM/GPRS-based group controller	Feeder panel	GSM/GPRS	5.0	0.0	**5.0**
GSM/GPRS-based individual lamp controller	Gateway	GSM/GPRS	5.0	1.0	**6.0**
LR-WPAN and Wi-Fi/2G/3G based individual lamp controller	Gateway	RF mesh	0.5	0.15	**0.65**

3.5.3. Smart irrigation pump control panels

There are over 20 million irrigation pump[7] sets connected to the grid in the country and a majority of them are inefficient and unmetered. Through the Bureau of Energy Efficiency (BEE) and EESL, the government has been promoting the use of BEE 5 star rated irrigation pump sets to improve end use energy efficiency in agriculture pumping. Drawing lessons from the various pilot projects implemented in the past, the government has envisaged a smart energy efficient irrigation pump (SEEIP) set solution to promote and upscale energy efficiency in agriculture pumping systems by considering the interests of all the key stakeholders, including farmers, the state government, distribution companies (DISCOMs) and third-party Ag DSM solution/service providers. Some of the key guiding factors in the design of an irrigation pump set efficiency upgrade solution are as follows:

- The proposed solution should facilitate a mechanism to monitor and verify the actual energy savings realised under the programme. This is essential to reduce the risk of deemed energy savings adopted in the earlier pilots.
- The solution must provide sustained energy savings assurance to the state government and DISCOM during the entire term of the project.
- The solution must garner sufficient buy-in from farmers, who don't have any incentive for energy savings in the current scenario.

The key features and functionalities enabled by the SEEIP sets solution are:

- The SEEIP solution consists of a BEE 5 Star IP set along with a smart electric control panel that will enable the farmer to operate the IP set remotely via mobile phone.
- The smart electric control panel will communicate real-time electrical performance parameters of the BEE 5 Star IP set (viz. phase-wise voltage, current, power factor, etc.) at predefined intervals remotely via wireless communication technologies to a central server in order to facilitate the verification and validation of energy savings.
- Only the IP set connections in the segregated agriculture feeders responding to supervisory control and data acquisition (SCADA) will be considered for replacement with SEEIP under the programmes.

[7] Indian Pump Manufactures Association (IPMA)

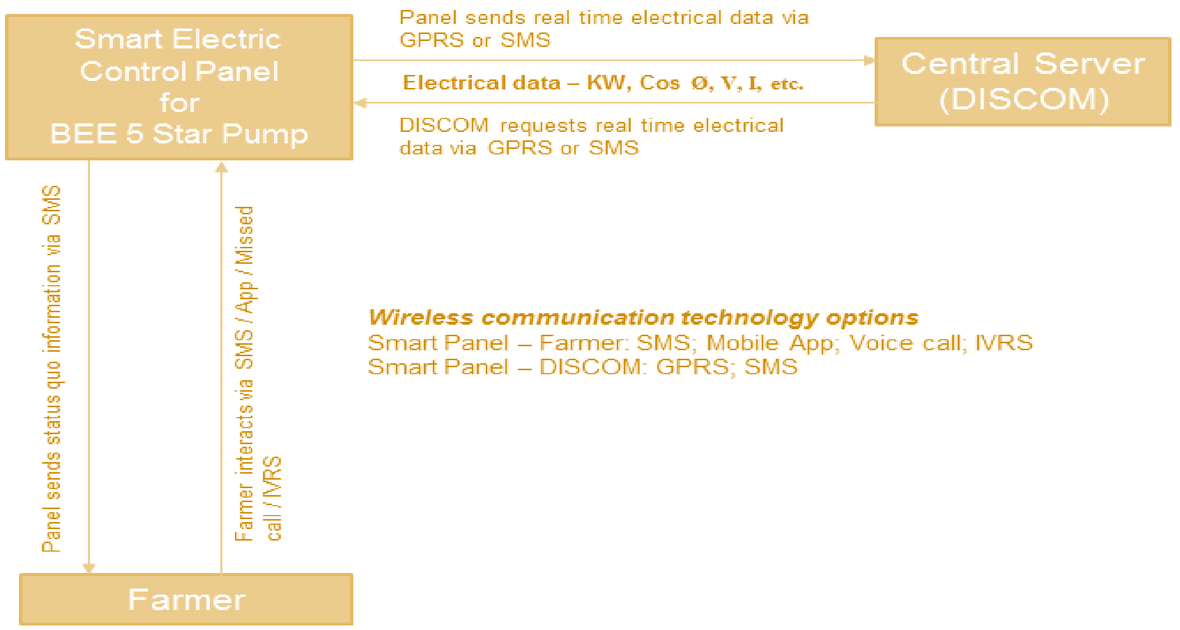
- The water output delivered by the SEEIP provided under this programme will be greater than or equal to the output of the old pump set.
- The input power rating of the SEEIP will be less than the measured input power of the old irrigation pump set at stable pumping conditions.
- Farmers will not incur any upfront cost towards the SEEIP provided under this programme.
- Farmers will receive a comprehensive warranty and repair/replacement service for five years towards the SEEIP without any cost burden.

Figure 5: Proposed SEEIP set solution

Figure 6: Potential benefits to stakeholders

Farmers	State government	DISCOM
• Enhanced social and financial security • Avoids inconvenience from operating IP sets during odd hours • Reduced expenditure on IP set maintenance and electricity bills	• Verified energy and subsidy savings • Reduced burden of electricity tariff subsidy provided to agriculture consumers • Improved fiscal deficit • Deferred investment towards new power generation capacity • Reduced CO2 emissions and other environmental benefits	• Verified energy savings • Reduction in energy and peak deficit • Reduction in aggregate technical and commerical (AT&C) losses • Reduction in transformer burnouts and replacement costs • Reduction of reactive energy losses in rural feeders • Improved financial health • Improved power supply quality

Figure 7: Physical configuration and communication architecture of smart electric control panels



a. Standby power data for smart agricultural control panel

This section compares the communication technologies employed by different smart agricultural control panels available in the Indian market and their standby power, as claimed by the manufacturers/vendors. All the existing smart panels use GSM-based communication technology as of now in India and hence, only one type of product is being considered here.

Table 4: Communication technology along with standby power data

Product	Gateway	Communi-cation technology	Power drawn by gateway in Watts	Net power drawn by single smart controller in Watts	Standby power of smart starter panel in Watts
GSM-based mobile starters	No	Quad-band GSM	-	10	**1.5**

3.5.4. Smart sockets

Smart sockets are emerging as one of the most popular IoT solutions in the home and building automation markets. Smart sockets are wireless communication-enabled sockets that offer the convenience of remote control plug loads anytime and from anywhere using Internet applications. Advanced solutions enable one to monitor certain information, such as power drawn, load and operational hours.

Smart plug products available in the market today can be plugged into an ordinary socket installed in homes and other buildings. The device itself has its own outlet, so in a sense it's like an outlet extension.

The benefit is that the smart plug can be controlled remotely, whether by using a home automation smart hub or connecting to the smart plug with the relevant mobile app. Some plugs are even programmable so that they automatically turn on or off depending on certain timers or events.

a. Standby power data for smart sockets

The following section compares communication technologies employed by different smart sockets available in the Indian market and their standby power as claimed by the manufacturers/vendors. All the existing smart sockets use either Wi-Fi or GSM-based communication technologies as of now in India and hence, only two types of products are being considered here.

Table 5: Communication technology along with standby power data

Product	Gateway	Communi-cation technology	Power drawn by gateway in Watts	Power drawn by smart plug in Watts	Net Standby power of smart plug in Watts
Wi-Fi based socket	No	Wi-Fi	0.0	3	**3**
GSM-based socket	No	GSM	0.0	1.76	**1.76**

3.5.5. Smart meters

Smart meters are at the heart of advanced metering infrastructure (AMI) and other smart grid systems envisaged in the country. A smart grid is an intelligent electrical grid that uses information and communication technologies (ICTs) to gather, monitor and act on real-time (interval) information about power system characteristics (viz. generation, end use/load, price/tariff, performance of power system components, etc.) in an automated fashion in order to improve the efficiency, reliability, economics, and sustainability of the production, transmission, distribution and end use consumption of electricity.

AMI is the principal smart grid system that constitutes smart meters, communication systems, computer-based hardware (data storage centres/servers) and software applications to gather and act on real-time information about end use energy in order to improve the efficiency and economics of end use electricity consumption.

Smart meters enable two-way communication between the meter and the user and utility HES. Unlike home energy monitors, smart meters can gather data for remote reporting. Such advanced AMI differs from traditional automatic meter reading (AMR) in that it enables two-way communication with the meter. Communication from the meter to the network can be done via fixed wired connections or wirelessly.

Core components of AMI	Minimum functionalities of AMI
• Smart meters • Communication infrastructure • HES • Meter data management system (MDMS) • Web application to view updated real-time data • Mobile application to enable customer participation	• Remote meter data reading at configurable intervals (push/pull) • ***Time of day (TOD)/ Time of Usage (TOU) metering*** • Pre-paid functionality • ***Net meter billing*** • Alarm/event detection, notification and reporting • Remote load limiter and connection/disconnection at defined/on demand conditions • Integration with other existing systems like IVRS, billing and collection software, GIS mapping, consumer indexing, new connections and disconnections, analytics software, and outage management system. • Security features to prevent unauthorised access to the AMI

In August 2015, the Bureau of Indian Standards (BIS), at the direction of the Ministry of Power (MoP), Government of India, published the new Smart Meter Standard, IS 16444: AC Static Direct Connected Watthour Smart Meter – Class 1 and 2 Specification covering single-phase energy meters; three-phase energy meters; single-phase energy meters with a net metering facility; and three-phase energy meters with a net metering facility. Another standard, IS 15959: Data Exchange for Electricity Meter Reading, Tariff and Load Control — Companion Specification, has been revised and published as IS 15959: Part 2-Smart Meter in March

2016. Also, as discussed in the earlier section, the Central Electricity Authority (CEA) has recently (June 2016) specified the functional requirements of AMI in India, along with detailed technical specifications for single- and three-phase whole current smart meters. As per these specifications, the smart meter should have the following minimum basic features:

- Measurement of electrical energy parameters
- Bidirectional communication
- Integrated load limiting switch
- Tamper event detection, recording and reporting
- Power event alarms such as loss of supply, low/high voltage
- Remote firmware upgrade
- Net metering features
- On demand reading

The MoP has recently announced the government's vision to roll out smart meters on fast track for customers with a monthly consumption of 500 kWh and above in Phase 1 by December 2017 and for customers with monthly consumption of 200 kWh and above in Phase 2 by December 2019. This is one of the salient goals envisaged for the operational efficiency improvement of DISCOMs under the UDAY scheme, which is the largest ongoing power sector reform in the country. This goal is also reiterated in the recent National Tariff Policy Amendments announced by the MoP.

DISCOMs across the country are expected to roll out 35 million smart meters as a result of the government's vision under the existing policy framework. The investment required to achieve this vision is a whopping 11,280 crore. INR

a. Standby power data for smart meters

This section compares communication technologies employed by different smart meters available in the Indian market and their standby power, as claimed by the manufacturers/vendors.

Table 6: Communication technology along with standby power data

Product	Gateway/ router	Communication technology	Power drawn by meter in Watts	Standby power of smart meter in Watts
Wi-Fi based meter	Router	Wi-Fi	0.9	**0.00045**
LoRa-based meter	Gateway	LoRa	0.128	**0.00924**
RF-based meter	No	RF	1.6	**0.025**

3.5.6. Smart air conditioner/thermostat

The evolution of smart homes has resulted in the installation of integrated and centralised control systems and smart appliances in homes. As a part of the smart home, smart air conditioners can be controlled using smartphones and provide increased comfort and convenience for consumers. Various developed and advanced features like remote control, wearables control, motion sensing and weather monitoring are added to smart air conditioners to improve the quality of life for end users.

Due to the uncontrolled use of air conditioners, large amounts of energy were wasted, leading to unnecessary expenses and environmental damage. With the use of the intelligence of the Internet, ACs have been turned into smart devices, thereby generating huge energy and cost savings through smart automation. The integration of technology like Wi-Fi, Bluetooth, and ZigBee provides a platform for information exchange between appliance and other systems.

The global smart connected air conditioner market is expected to grow at a CAGR of 60.42% during the period 2016–2020[8]. The market size has been calculated based on the revenue generated in the residential consumer segment from the sale of inbuilt smart connected air conditioners. Smart features like connectivity, remote prognostics and easy fault detection features are the reasons for the increase in demand for such products in the market.

a. Standby power data for smart ACs

The following section compares the communication technologies employed by the different smart ACs available in the Indian market and their standby power, as claimed by the manufacturers/vendors. All the existing smart ACs use either Wi-Fi/RF or cloud-based communication technologies as of now in India and hence, only two types of products are being considered here.

Table 7: Communication technology along with standby power data

Product	Gateway	Communication technology	Power drawn by IoT element in Watts	Standby power of IoT element in Watts
Wi-Fi based AC	No	Wi-Fi, RF	-	**0.1**
Wi-Fi AC + app	No	Wi-Fi	0.3-0.4	**0.001**

3.5.7. Smart geysers

A smart geyser is a self-regulated water heating device that provides hot water by understanding the user's routine consumption pattern. It is one of the products that is driven by the IoT wave. The need for automation to remotely control and monitor the operation of geysers, along with energy efficiency, is one of the key driving factors behind this device.

By 2020, the electric geyser segment will continue its dominance over the global geyser market by accounting for almost 39% of the overall market share[9]. Rising awareness of energy efficiency and the green nature of automated temperature control geysers are estimated to favour the growth of this market segment in the coming years. Furthermore, a growing number of government initiatives to improve rural infrastructure and ensure uninterrupted supply of electricity in developing economies will also trigger an increase in the demand for smart geysers.

On the technological front, network elements are used to collect real-time data from sensors embedded in geysers. This results in IoT-enabled devices that log real-time information about use, temperatures, energy consumption, and malfunctions in geysers. The device is linked through a smartphone app and is controlled through a different communication network, depending on the network element used. The smart geyser provides notifications regarding energy consumption details and alerts the user if the device is running dry and to cut off power immediately. It also has the capability to self-diagnose any problems and automatically inform the service centre. In order to turn on/off the geyser, a set time is configured which automatically activates the desired mode.

a. Standby power data for smart geyser

This section compares communication technologies employed by different smart geysers available in the Indian market and their standby power, as claimed by the manufacturers/vendors. Currently, all the existing smart geysers in India use Wi-Fi communication technology and hence, only one type of product is being considered here.

[8] Global smart connected air conditioner market 2016-2020, Research and Markets report
[9] Global geysers market to witness the emergence of smart geysers by 2020, Technavio, in press

Table 8: Communication technology along with standby power data

Product	Gateway	Communication technology	Power drawn by gateway in Watts	Standby power of IoT element in Watts
Wi-Fi based smart geyser	Yes	Wi-Fi, IR remote technology	0.4	**0.001**

3.5.8. Smart refrigerators

Smart refrigerator has changed its generalised definition. Value proposition, a much enhanced operating functionality, enables the customer to opt for this appliance. A smart refrigerator is a technologically advanced refrigerator which is programmed to sense the kind of products being stored inside it and thus recording them through barcode or RIFD scanning. It is often equipped to determine whenever a food item needs to be replenished and sends a message to inform the owner about the situation of the stock in the refrigerator using a communication network such as Wi-Fi.

The smart refrigerator market is expected to expand globally at a CAGR of 15.5% over 2017–2024[10]. The market is expected to witness lucrative growth in the near future owing to the rise in the need for advanced refrigerators for consumers. The demand for smart refrigerator is rising owing to rapid growth in urbanisation, a growing concern for electricity cost, awareness of energy efficiency and availability of innovative and affordable smart refrigerators in the market.

On the technology front, the smart refrigerator not only has a giant touch-screen on the front—it also clubs a small camera that lets a user see the status of the process through it. Users can convey a voice command to learn the weather and time, add products to the shopping cart and order groceries online, manage to-do-lists as well as calendar schedules, in addition to controlling various other apps. Instantaneous cooling, in-fridge humidity, food scanning and the capability to run different parts of the refrigerator at different temperatures are some of the drivers behind the demand for smart refrigerators.

a. Standby power data for smart refrigerators

This section compares the communication technologies employed by different smart refrigerators available in the Indian market and their standby power, as claimed by the manufacturers/vendors. All the existing smart refrigerators use RF-based communication technology as of now in India and hence, only one type of product is being considered here.

Table 9: Communication technology along with standby power data

Product	Gateway	Communication technology	Power drawn by gateway in Watts	Standby power of IoT element in Watts
RF-based refrigerator	No	RF frequency	-	**0.001**

3.5.9. Smart TVs

A smart television is a television set with integrated Internet capabilities, or a television set-top box that offers advanced connectivity as well as computing abilities. The main functions of a smart TV are relaying content such as photographs, movies, and music from devices attached to it using a Digital Living Network Alliance such as Windows Media Player and providing access to broadcast TV channels and Internet-based services such as catch-up services and video-on-demand.

Smart TVs are being adopted in the global market primarily based on the increasing demand for web-enabled TVs from individual customers, encouraged by the number of functions and features offered by the smart TV,

[10] Smart refrigerator market: Global demand analysis & opportunity outlook 2024, Research Nester report

the rising Internet population, increasing customer spending on consumer electronics and steady development of entertainment technologies.

The global smart TV market is expected to reach 198.2 million units in terms of unit shipments in 2017, growing at a CAGR of 20.8% during 2012–2017. In terms of unit shipments, India's smart TV market is expected to reach 9.86 million units by 2017, growing at a CAGR of 109.93% for the same period.[11]

a. Standby power data for smart TV

The following section compares communication technologies employed by different smart TVs available in the Indian market and their standby power, as claimed by the manufacturers/vendors. All the existing smart TVs use Wi-Fi communication technology as of now in India and hence, only one product is being considered here.

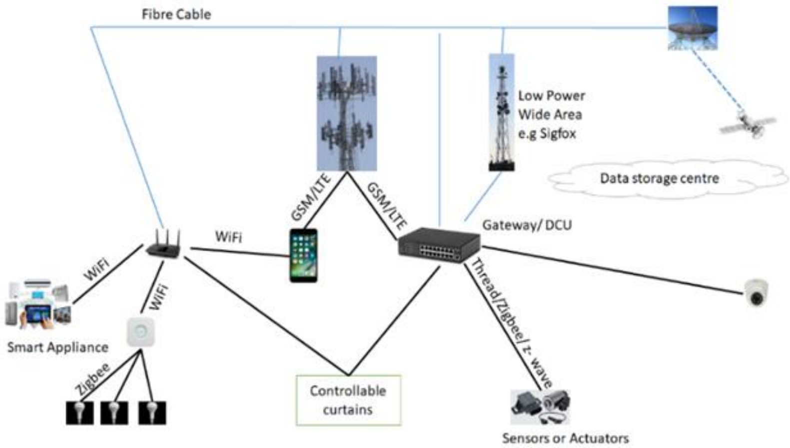
Table 10: Communication technology along with standby power data

Product	Gateway	Communication technology	Power drawn by IoT element in Watts	Standby power of IoT element in Watts
Wi-Fi based TV	No	Wi-Fi	0.3	**0.001**

3.5.10. Home and building automation

In the era of smart cities, smart homes is supposed to be one of the key ingredients. Home automation systems allow an owner to control lighting, heating and cooling, security cameras and other functions. Control systems simplify the entire entertainment system, to run all equipment precisely and efficiently.

Figure 8: Home automated ecosystem



Lighting control modules can also be added to the system to minimise the power drawn by automating the turning on and off of lighting depending on occupancy. Additionally, automation of thermostats can greatly help in keeping the house cool or warm depending on the weather or time of the year. The app or the user interface sends a message to the server or the cloud from where the data is transmitted to the gateway and subsequently, the gateway process the command and sends a signal to the end device to carry out the operation.

All of these systems can be monitored and can also display the power drawn in real time on a smartphone, TV, iPad or any other display device. Scheduling and energy monitoring creates immense energy efficiency potential for home automation.

[11] Smart TV market (2012-2017): Global market forecast by display size, technology (2D & 3D), geography (North America (US, Canada, others), Europe (Germany, UK, France, Italy, others), Asia- Pacific (China, Japan, others) and RoW (Middle East, Africa, Latin America), 6Wresearch report

The home automation system market is expected to be worth 79.57 billion USD by 2022, growing at a CAGR of 11.3% and with the APAC region contributing the highest due to the strengthening of infrastructure.[12] Major factors for the growth of the home automation system market are growth in IoT, cost reduction measures, a large number of manufacturers widening their product portfolios, and the increasing importance of remote home monitoring.

The proactive segment is expected to hold the largest size of the home automation system market as it is specifically designed to enable consumers to understand energy patterns and take effective measures to reduce their consumption. They can also send recommendation signals to end users for taking necessary energy reduction actions and can accordingly control the smart devices.

a. Standby power data for home automation systems

This section compares the communication technologies employed by different smart home and building automation systems available in the Indian market and their standby power, as claimed by the manufacturers/ vendors. All the existing home and building automation systems use either KNX or ZigBee/Wi-Fi based connectivity as of now in India and hence, only two types of products are being considered here.

Table 11: Communication technology along with standby power data

Product	Gateway	Communication technology	Power drawn by gateway in Watts	Standby power of gateway in Watts
KNX-based home automation system	Yes	KNX	10	**1**
ZigBee/Wi-Fi based home automation system	Yes	ZigBee/Wi-Fi	10	**10**

Detailed product profiles under each IoT solution have been presented in the attached annexure.

[12] Retrieved from http://www.prnewswire.com/news-releases/home-automation-system-market-at-a-cagr-of-113-during-2017-to-2022---reportsnreports-619391534.html

4. Task II – Examination of the IoT communication technology landscape in India

This chapter presents the basic requirements to send or receive data within two devices or networks. It lists the currently available communication technologies, their characteristics and delicensed/licensed bands operated in India. And finally, a technology fit for different application areas has been developed.

4.1. Communication requirements

IoT will revolutionise and change the way all businesses, governments and consumers interact with the physical world. The IoT ecosystem may have devices, gateways, communication technologies, big data and process management, IoT platforms, etc. IoT will have a heterogeneous network, having Internet protocol and non-Internet Protocol based devices connected through Internet Protocol gateways which will further be connected to IoT platforms. Different applications will have different bandwidth and latency requirements.

For example, smart metering requires less bandwidth with no severe latency conditions, whereas some critical applications like healthcare applications may pose requirements of higher bandwidth and improved latency. Apart from availability, reliability of communication networks is a key characteristic for critical applications. Using standards-based technologies will ensure a high degree of scalability and interoperability. The choice of operating frequency is vital for deciding the power drawn by the devices and the range of the communications network. Having a long technology life cycle, compliance with regulations and total cost of ownership are other key characteristics. Moreover, all communication technologies must possess the necessary measures to be resilient to cyberattacks.

The IoT communications infrastructure is composed of:

- The **core network** supports the connection between numerous gateways and headquarters. The backbone network requires high capacity and bandwidth availability and is usually built on optical fibres.
- The **last mile** covers the areas of the neighbourhood area network (NAN). There are many available wired and wireless technologies that must provision broadband speed and security.
- The **premises network** supports the home area network (HAN) dedicated to effectively managing the on-demand power requirements of the end users and associated building automation.

Some of the criteria for choosing the appropriate communication technologies are mentioned below:

#	Criteria	Description
1	Data integrity and security	• Data to be used for billing purposes – requires higher level of transmission integrity • Data encryption to avoid data loss and data hacking
2	Communication range	• Range will depend upon application
3	Spectrum availability and operating frequency	• Licensed, worldwide availability • Unlicensed – but should be more reliable and cost-effective
4	Interoperability	• Devices from different manufacturers shall be compatible with each other
5	Cost effectiveness	• Cost – the main driving and deciding factor

#	Criteria	Description
		• Includes installation, maintenance, frequency band and power drawn
6	Battery life/power consumption	• Required for communication when power supply is interrupted • Long battery life to reduce device maintenance and manual intervention • Selected technology shall not consume more than it saves
7	Data rate	• Smart metering/lighting/appliances – small amount of data to be transmitted • Typical data transmission frequency requirement: - Every 15 minutes for electricity consumption data required for smart meters - For other applications like lighting/appliances, data may be pushed or pulled whenever required

4.2. Available technologies

Several communication technologies are available today. The following are the popular options for the last-mile network/ NAN/wide area network (WAN): 6LoWPAN-based and other communication-based RF mesh, ZigBee, Wi-Fi, power line carrier (PLC), Ethernet and serial interfaces. For the HAN, 6LoWPAN-based RF mesh, ZigBee, Wi-Fi, Bluetooth, Z-Wave, near field communications (NFC), PLC, Ethernet, LoRa and serial interfaces are being used commonly. Depending upon the requirements, cellular and satellite communications, low power wide area (LPWA) technology, long wave radio, television white space (TVWS), optical fibre, Ethernet, PLC, digital subscriber Line (DSL) etc., could be used for the backhaul/WAN and backbone networks.

4.2.1. Wi-Fi

Wi-Fi technology is basically based on the IEEE 802.11 standards. Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing of devices that can use Wi-Fi technology, which includes personal computers, video-game consoles, smartphones, digital cameras, tablet computers, smart TVs, digital audio players and modern printers. Wi-Fi compatible devices can connect to the Internet via a WLAN and a wireless access point. Such an access point (or hotspot) has a lower range when used indoors and provides a greater range outdoors. Wi-Fi most commonly uses the 2.4 gigahertz and 5 gigahertz radio bands. Having no physical connections, it is more vulnerable to attack than wired connections such as Ethernet.

4.2.2. Bluetooth

Bluetooth is a wireless technology for exchanging data over short distances with a data throughput of 720 Kbps. The communication range varies from up to 100 m and operates at the 2.4 GHz frequency band. This is designed with the intention of exchanging bulk continuous data at short range and hence consumes a lot of battery power. Bluetooth low energy (BLE), indicated by Bluetooth Smart or Bluetooth 4.0, is a low-power wireless technology, which is also capable of running the device with a tiny battery (backup power) for a long time.

4.2.3. Mesh network

Many mesh networks have been explored over the past decade or so. Mesh networks use short-range, high data rate wireless technologies to build a network that depends on relaying data between nodes. Some of the communication technologies which are used as part of mesh network are ZigBee, Z-Wave, 6LoWPAN, Wi-Sun etc.

Table 12: Mesh technologies overview

#	LPWAN technologies	Description
1	Wi-Sun	• Wireless Smart Ubiquitous Network (Wi-SUN) is a technology based on the IEEE 802.15.4g standard.
2	6LoWPAN	• It is a low-power wireless mesh network where every node has its own IPv6 address, allowing it to connect directly to the Internet using open standards.
3	Z-Wave	• It is a low-powered RF communication technology that supports full mesh networks without the need for a coordinator node and operates in the sub-1 GHz band, impervious to interference from Wi-Fi and other wireless technologies in the 2.4-GHz range.

4.2.4. Cellular

This type of network supports long-range communication by using the cellular network of telecom service providers. Although 2G and 3G cellular networks are mainly used in cellular IoT services, the LTE is an emerging technology for M2M communication. A 2G- or 3G-enabled SIM card has to be inserted into smartphones or to tablets through which smart devices communicate to the Internet.

4.2.5. LPWAN

The LPWAN class of protocols consists of low bitrate communication technologies for such IoT scenarios. LPWAN technology is suitable for sending small amounts of data over a long range while maintaining long battery life. Some IoT applications only need to transmit tiny amounts of information and the low power of LPWAN allows that task to be carried out with minimal cost and battery draw. Some of the communication technologies which are used in LPWAN are narrow band IoT (NB-IoT), Sigfox, Weightless and Lora WAN.

Table 13: Overview of LP WAN technologies

#	LPWAN technologies	Description
1	LoRa	• LoRa is a LPWAN specification based on chirp spread spectrum radios.
2	NB-IoT	• NB-IoT is a new mobile technology specification by the 3GPP standards body, and is expected to be used for low power and infrequent data transmission devices. NB-IoT can operate in the GSM spectrum or utilise an unused resource block within a LTE's carrier's guard band.

4.2.6. Power line carrier (PLC)

Reliable, low-cost PLC technology enables ubiquitous home automation, street lighting and smart metering applications. PLC utilises infrastructure already present, eliminating the unnecessary expense and inconvenience of new wires or antenna-based networks. Various standards which are applicable for narrowband and broadband PLC are mentioned below; they operate at different frequencies:

Table 14: PLC bands overview

#	PLC bands	Description
1	Narrowband	• Globally, IEEE 1901.21, PRIME, G3-PLC, ITU-T, IEC 61334, TWACS, Meters&More, OSGP and HomePlug C&C are some of the

#	PLC bands	Description
		popular standards/protocols available for implementing narrowband PLC systems.
2	Broadband	• Globally, IEEE 1901-2010, HomePlug Green PHY and ITU-T G.hn (G.9960/G.9961) are some of the popular standards/protocols for implementing broadband PLC systems.

Table 15: Snapshot of available communication technologies/protocols

Technology/ protocol	Backhaul/WAN and backbone	Last mile/NAN/FAN	HAN
Wireless	Cellular, satellite, LPWA, long wave radio, TVWS, private microwave radio links (P2P and P2MP)	RF mesh, ZigBee, Wi-Fi, millimetre wave technology	RF mesh 6LoWPAN, LoRa, ZigBee, Wi-Fi, Bluetooth, Z-Wave, NFC, LoRa
Wired	Optical fibre, Ethernet, PLC, DSL	PLC, Ethernet, serial interfaces (RS-232, RS-422, RS-485), DSL	PLC, Ethernet, serial interfaces (RS-232, RS-422, RS-485)

The selection of a technology will depend on the envisaged application. For mission critical applications, security, reliability and latency will be the key criteria for deciding a communication technology. Cost will not be the main criterion. For non-critical applications such as AMI, electric vehicles, lighting and appliances, cost will be decisive. Figure 9 depicts the typical M2M/IoT network and communications used at various levels.

Figure 9: Typical M2M/IoT connections

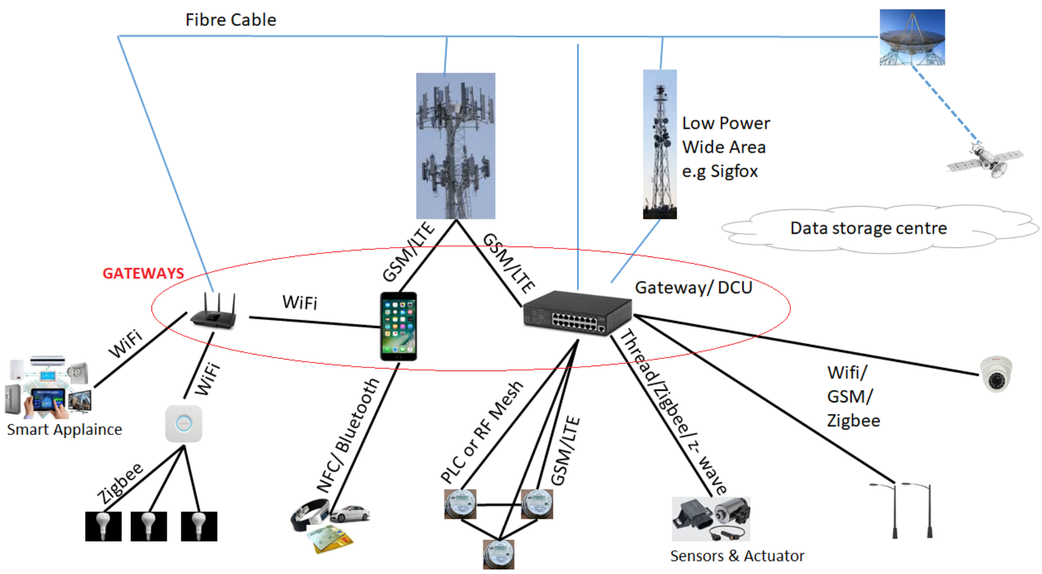


Figure 10: Illustrative mapping of IoT communication technologies

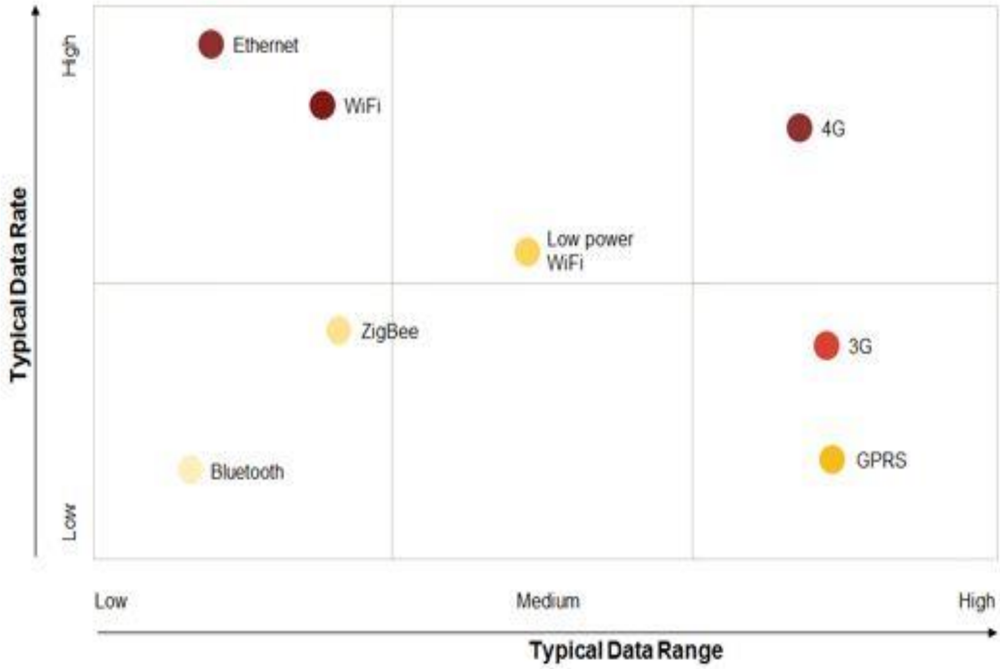


Table 16: Illustrative characteristics to be mapped for different IoT communication technologies[13][14][15][16][17][18]

Technology	Range	Data transmission mode	Average power drawn	Latency	Typical data transfer rate	Advantages	Limitations	Frequency Band (s)	Suitable applications
Wi-Fi	Indoor: 10 m Outdoor/LoS: 100 m	Continuous transmission of large data	Very high	~1.5 ms	54 Mbps (IEEE 802.11n)	• Mature technology • High home/office penetration • High data rates achievable • Easy to implement • Very low total cost of ownership (TCO) • Low cost communication modules • Negligible operating cost	• Limited range • Poor building penetration • High interference from other sources • Power drawn higher than those technologies that operate in the sub-GHz band	2.4 GHz	• Base station in Health Clinics • Smart Metering • Home Automation
ZigBee	Indoor: 10 m Outdoor/LoS: 300 m	Sporadic transmission of small data	Low	~20 ms	250 Kbps	Longer battery life from low-cost coin cells for wearable devices Wireless range up to 70 m indoor and 400 m outdoor	• Short range	2.4 GHz, 920 MHz, 915 MHz, 868 MHz, 780 MHz	• Health monitoring and safety • Client activity monitoring • Health and wellness monitoring • Smart metering

[13] https://pdfs.semanticscholar.org/d359/135b9aba3ce3e77c687d6e8cef53c23f3452.pdf
[14] http://www.ari.vt.edu/US-ChinaWorkshop2014/style/resources/paper_murat.pdf
[15] https://www.vs.inf.ethz.ch/edu/FS2014/UCS/reports/DominikKovacs_Communication_report.pdf
[16] ISGF work with TEC
[17] https://www.u-blox.com/sites/default/files/ShortRange-InternetOfThings_WhitePaper_%28UBX-14054570%29.pdf
[18] Data Transmission and Reception using Power Line Communication

Technology	Range	Data transmission mode	Average power drawn	Latency	Typical data transfer rate	Advantages	Limitations	Frequency Band (s)	Suitable applications
Bluetooth low energy	Indoor: 10 m Outdoor/LoS: 100 m	Sporadic transmission of small data	Medium	~7.5 ms	1 Mbps	• Mature technology • Easy to implement • Low power • Powered by coin cell • Longer battery life	• Small data packets • Short range • Need access points (phone or application-specific device)	2.4 GHz-2.483 GHz	• Healthcare devices • Fitness devices • Smart metering
LoRaWAN	Indoor: 2–5 km Outdoor/LoS: 15 km	Small data	Low	1-2 s	9.6 Mbps	• Low power	Small data packets	865 MHz–867 MHz	• Smart lighting • Air quality and pollution monitoring • Smart parking and vehicle management • Facilities and infrastructure management • Fire detection • Waste management
Ethernet	Cable: 100 m	Continuous transmission of large data	Very high	Immediate	2–600 Mbps	• Mature technology • Reliable • Easily scalable	• Lowest data security • Highest latency • Bursts of additional bandwidth not possible	16,100,250 ,500, 600 MHz, 1 GHz, 1.6–2.0 GHz	• Gateway for remote health monitoring • Concentrator for tele-health • Smart metering • Home automation

Technology	Range	Data transmission mode	Average power drawn	Latency	Typical data transfer rate	Advantages	Limitations	Frequency Band (s)	Suitable applications
Cellular (2G, 3G, LTE, NB-IOT)	Urban: ~5 km Outdoor/LoS: >10 km<50 km	Continuous transmission of medium data	High	Immediate	56 kbps–2 Mbps	• Mature technology • Rapid deployment • Communication modules are low cost and standardised	• Coverage not 100% • Reliability not the best • Short technology lifecycle (2G, EDGE, 3G, LTE etc.)	For India, 900 MHz, 1800 MHz, 2100 MHz and 2,300 MHz are Allocated	• Smart metering • Smart sockets • Home automation
NFC	20 cm	Small data	Low	~ polled every second, this is manufacturer specific	848 kbps	• Consumes less power • Almost instantaneous connectivity between devices • No power is required in case of passive tags	• Extremely short range • Expensive • Low information security • Low market penetration	13.56 MHz	• Healthcare devices • Fitness devices • Smart Metering
Z-Wave	100 m	Small data	Low	Low latency	9.6 kbps–100 kbps	• Successful due to its ease of use and interoperability • Majority share of the home automation market	• Proprietary radio systems available • Limited range drives up costs	868.42 MHz, 908.42 MHz	• Security systems • Home Automation • Lighting controls
Wi-Sun	1000 m	Medium data	Low	0.02 s	50 kbps – 1 Mbps		Not very popular	2.4 GHz	• FAN and HAN • Smart utility networks • smart grid

Technology	Range	Data transmission mode	Average power drawn	Latency	Typical data transfer rate	Advantages	Limitations	Frequency Band (s)	Suitable applications
PLC	Short range: 0–80 km Medium range: 80–250 km Large range: >250 km[1]	Large data	NA		100–500 kbps	• Ready infrastructure • Communication possible in challenging environments • Long technology life cycle • Many standards and protocols available	• Point-to-point communication • Can cause disturbances on the lines • Not suitable where power cables are not in a good condition • Initial and ongoing line conditioning and maintenance can add significant O&M costs • Communication not possible in case of an outage • Absence of regulations on use of frequency bands	No defined frequency band in India	• Smart metering • Home automation

Very low: <1 mille W
Low: 1–10 mille W
Medium: 10–100 mille W
High: 100 mille W–1 W
Very High: >1 W
LoS: Line of sight

4.3. Choice of frequency band

Selecting the frequency band is of utmost importance. The sub-GHz frequency bands offer compelling advantages as compared to other (higher) frequency bands. Below 1 GHz, the further down we go, the better the performance will be in terms of range, interference and penetration. This assumes that the devices will only be sending an incremental amount of data at regular intervals. The advantages of using a lower frequency band include (but are not limited to):

- **Long range**

The range is inversely proportional to frequency and hence the range at the same output power and receiver sensitivity offered by sub-GHz bands is much more than that provided by the higher frequency bands.

- **High signal-to-noise ratio**

The 2.4–2.4835 GHz band is used by Wi-Fi and Bluetooth devices, microwave ovens, cordless phones, etc. This has increased the traffic in this band and hence interference is a serious issue. The sub-GHz bands are much less congested and hence offer enhanced quality of service.

- **Low power consumption**

Since the power dissipation is directly proportional to frequency of operation, a device operating in sub-GHz bands will consume less power.

- **Deep penetration**

Since low-frequency signals are reflected to a lesser extent, signals in the sub-GHz bands penetrate deeper into thick walls.

- **Low TCO**

Since sub-GHz bands offer a higher range at the same output power and receiver sensitivity, fewer repeaters/concentrators are needed. Hence, the TCO is lower when sub-GHz bands are used.

4.3.1. Current scenario of delicensed bands in India:

a. 433–434 MHz band

As per the G.S.R. 680 (E) notification, this frequency band was delicensed in September 2012. The specifications require that the maximum effective radiated power and maximum channel bandwidth be 10 mille W and 10 KHz respectively. In addition to using an in-built antenna, the devices (that operate on this frequency band) are meant for indoor applications only. Currently, there are very few devices in this band.

b. 865–867 MHz band

As per the G.S.R. 168 (E) notification, this frequency band was delicensed in March 2005. The specifications require that the maximum transmitted power, maximum effective radiated power and maximum channel bandwidth be 1 W, 4 W and 200 KHz respectively. This band can be used for radio frequency identification (RFID) or any other low-power wireless devices or equipment.

Currently, this band is not congested as M2M/IoT/smart cities initiatives are still gathering pace. However, with the introduction of more and more devices, this frequency band may not remain adequate to meet the expected demand.

c. 2.4–2.4835 GHz band

As per the G.S.R. 45 (E) notification, this frequency band was delicensed in January 2005. The specifications require that the maximum transmitted power, maximum effective radiated power and maximum antenna height be 1 W (in a spread of 10 MHz or higher), 4 W and within 5 m above the rooftop of an existing authorised building respectively. This band can be used for any wireless equipment or device.

At present, too many devices use this frequency band. These include (but are not limited to) Wi-Fi and Bluetooth devices, microwave ovens and cordless phones. High interference, limited range and high-power dissipation (of the devices) limit the use of this band for M2M/IoT/smart cities.

d. 5.150–5.350 GHz band and 5.725– 5.875 GHz band

As per G.S.R. 46 (E), these frequency bands were delicensed in January 2005. The specifications require that the maximum mean effective isotropic radiated power and maximum mean effective isotropic radiated power density be 200 mille W and 10 mille W/MHz respectively in any 1 MHz band. In addition, the antenna must be in-built or indoor. This band can be used for indoor applications only. These include usage within the single contiguous campus of an individual, duly recognised organisation or institution.

Although this frequency band offers low interference, it is not widely used in today's scenario.

e. The 5.825–5.875 GHz band

As per the G.S.R. 38 (E) notification, this frequency band was delicensed in January 2007. The specifications require that the maximum transmitted power and the maximum effective isotropic radiated power be 1 W (in a spread of 10 MHz or higher) and 4 W respectively. This band can be used for any wireless equipment or device.

This frequency band also offers low interference, but will not be ideal for low-power applications due to relatively high power dissipation and limited range. However, this band could be used for point to point and point to multipoint links.

The following table summarises the above-mentioned specifications:

Table 17: Summary of specifications of delicensed bands

Frequency band	Power requirements	Antenna	Use of this frequency band
433–434 MHz	• Maximum effective radiated power: 10 mille W • Maximum channel bandwidth: 10 KHz	In-built	Indoor applications
865–867 MHz	• Maximum transmitted power: 1 W • Maximum effective radiated power: 4 W • Maximum channel bandwidth: 200 KHz	Nothing specified	Any low power device or equipment
2.4–2.4835 MHz	• Maximum transmitted power: 1W (in a spread of 10 MHz or higher) • Maximum effective radiated power: 4W Maximum antenna height: 5 m above the rooftop of an existing authorized building	Nothing specified	Any low power device or equipment
5.150–5.350 GHz and 5.725–5.875 GHz	• Maximum mean effective isotropic radiated power: 200 mille W • Maximum mean effective isotropic radiated power density: 10 mille W/MHz in any 1 MHz band	In-built or indoor	Indoor applications which include single contiguous campus of an individual, duly recognised organisation or institution

Frequency band	Power requirements	Antenna	Use of this frequency band
5.825–5.875 GHz	• Maximum transmitted power: 1 W in a spread of 10 MHz • Maximum effective isotropic radiated power: 4W	Nothing specified	Any low-power device or equipment installed at outdoor locations

The existing 865–867 MHz band may not be enough for billions of connected devices (in smart grids, IoTM2M and the smart cities space). Limited spectrum may lead to packet drops and other RF issues. Most countries have allocated a wider band for low-power RF applications.

Globally, various countries have allocated unlicensed frequency bands in excess of 7 MHz. North America and South America have allocated the most (26 MHz) in the sub-GHz band. Australia also believes that delicensing a substantial amount of spectrum is the way forward and has allocated 13 MHz. Europe, Africa and most Middle Eastern countries have access to 7 MHz of unlicensed spectrum. Moreover, Japan has delicensed 8 MHz for IoT/IoE/M2M/smart cities initiatives. The following table shows wireless frequency spectrum allocation in some countries/regions:

Table 18: Global frequency spectrum allocation scenario

Country	Frequency band
North America and South America	433.075–434.775 MHz and 902–928 MHz
Africa and Middle Eastern countries	433.05–434.79 MHz and 863–870 MHz
Europe	433.05–434.79 MHz, 863–870 MHz, 870–876 MHz
Japan	426–430 MHz and 920–928 MHz
Australia	915–928 MHz
India	865-867 MHz and 433–434 MHz

4.4. Preferred technologies

The choice of communication technology directly affects the device hardware requirement and, therefore, cost is also effected. Different applications (critical or non-critical requirement, etc.) need different communication requirements. A few of the applications, along with their communication requirements which were studied as part of this study, are mentioned below:

4.4.1. Smart street lights

Smart street lighting has evolved from oiled ignited lamps (140 BC) to the present-day electricity-powered street light system which is controlled from remote control centre. Now with the merging of IoT technologies with the street light systems, the present light system has become smarter. Smart street lighting has low communication requirements:

- Sporadic transmission
- Small data volumes
- Low latency requirements (0–20 mille s)

The following communication technologies are used presently:

- ZigBee

- Wi-Fi
- GSM
- Ethernet
- PLC

In the example discussed in the previous section, the street light system uses a combination of two technologies for communication—for example ZigBee is used from street lights to gateway and Wi-Fi/GSM/Ethernet/PLC is used from gateway to control centre. The sensor present in the street light system senses the ambient atmospheric light conditions and adjusts the light intensity accordingly. The IoT device embedded in the above example can also be battery powered, so the standby power requirement is very low.

The use of a mix of technology is the better option. RF technology can be preferred over other communication technology for data transmission between street lights and the gateway, and Ethernet can be preferred for communication between the gateway and control centre, as the standby power requirement is less than 150 mille W.

3G/4G is not recommended for communication between the gateway and control centre in view of the higher standby power requirement. Also, the active power requirement is higher than that of other IoT technologies.

Other possible technologies include:

- LoRa
- Sigfox
- Wi-SUN

4.4.2. Smart light bulbs

The smart light bulb has very low communication requirements:

- Household lights are switched off less often or dimmed as per mood requirements.
- Very low data volume
- Low latency requirement (1.5 mille s)

The following communication technologies are used presently:

- GSM
- ZigBee
- Wi-Fi

The example considered for the study uses a combination of two technologies. ZigBee is used from smart light bulbs to the bridge, and Wi-Fi is used from the bridge to the router. Other technologies mentioned above are also available for the operation. But, in view of low active power and low latency, Wi-Fi is best available technology.

Other possible technologies include:

- LoRa
- Sigfox
- PLC
- Weightless

4.4.3. Smart sockets

Smart sockets have moderate communication requirements:

- Continuous transmission: Energy consumption data is transmitted continuously to the mobile application.
- Moderate data volume: The motion sensors present in the sockets sense detection and energy onsumption data is sent to the smartphone app.
- Moderate latency requirement: 10 mille s (max.)

The following communication technologies are used presently:

- Wi-Fi
- GSM

The most appropriate technology for standby power is GSM. It has a low active power and standby power requirement and also no gateway is needed—i.e. direct communication between the device and sockets is possible, so no additional standby power for the gateway is needed. Also, with this advantage, the latency for the same will be less.

Other possible technologies include:

- LoRa
- Sigfox
- PLC
- Weightless

4.4.4. Smart meters

The smart meter has moderate communication requirements:

- Continues data transmission: Energy consumption data is transmitted continuously to Data Concentrator Unit (DCU).
- Moderate data volume
- Low latency requirement: 20 mille s – 3 s (max.)

The following communication technologies are used presently:

- Wi-Fi
- LoRa
- GPRS
- RF
- PLC

The selection of the communication technology will always be based on the landscape topology and other requirements like the number of meters to be covered. However, the most appropriate technology for standby power is low-powered RF technology. The latency requirement for meters is low—i.e. 1.5 milliseconds—for which RF is acceptable.

Other possible technologies include:

- ZigBee
- Z-Wave
- Wi-Sun

The table below shows the communication requirements of the investigated communication technologies considering various parameters like range, latency, frequency and data rate.

Table 19: Communication requirement of investigated communication technologies

IoT solution	Criteria	Requirement		
		Low	Medium	High
Smart light bulb (Wi-Fi)	Range	150 m		
	Latency	1.5 mille s		
	Frequency	2.4 GHz		
	Data rate	50 Mbps		
Smart light bulb (ZigBee)	Range	100m		
	Latency	20 mille s		
	Frequency	2.4 GHz		
	Data rate	250 kbps		
Home automation (Wi-Fi)	Range	500 m		
	Latency	1-2 mille s		
	Frequency	2.4 GHz		
	Data rate	9600 bit/s		
Home automation (KNX)	Range	30 m		
	Latency	1-2 mille s		
	Frequency	868 MHz		
	Data rate	9600 bit/s		
Smart sockets (Wi-Fi)	Range	500 m		
	Latency	1.5 mille s		
	Frequency	2.4 GHz		
	Data rate	13 Mbps		
Smart sockets (GSM)	Range	Can be controlled from anywhere		
	Latency	10 s		
	Frequency	1,900–2,100 MHz[1]		
	Data rate	9.6 kbps		
Smart street light (Wi-Fi)	Range	600 m		
	Latency	1.5 mille s		
	Frequency	2.4 GHz		
	Data rate	13 mbps		
Smart street light (3G/4G)	Range	600 m		
	Latency	10 s		

IoT solution	Criteria	Requirement		
		Low	Medium	High
	Frequency	1,900–2,100 MHz[1]		
	Data rate	500 Mbps (max)		
Smart street light (RF Mesh)	Range	150 m		
	Latency	100 mille s		
	Frequency	868 MHz		
	Data rate	9.6 kbps		
Smart appliances (Wi-Fi)	Range	20 m		
	Latency	200 mille s		
	Frequency	2.4 GHz		
	Data rate	1 Mbps		

Range	Latency	Frequency	Data rate
Low: <50 m	Low: 0–10 mille s	Low: <1 GHz	Low: <100 kbps
Medium: 50–200 m	Medium: 10–25 mille s	Medium: 1–2 GHz	Medium: 100 kbps–1 Mbps
High: >200 m	High: > 25 mille s	High: >2	GHz High: > 1 Mbps

The table below shows the best suited communication technologies for the applications considered in this study.

Table 20: Communication technology fit for various IoT solutions

	Wi-Fi	ZigBee	LoRa	Cellular	KNX	6LowPAN	Z-Wave	PLC	Ethernet
Smart street lights	✓	✓	✓	✓	✓	×	×	✓	×
Smart light bulbs	✓	✓	✓	×	×	×	×	×	×
Home automation systems	✓	✓	✓	×	✓	✓	✓	×	×
Smart sockets	✓	✓	✓	✓	×	✓	✓	×	×
Smart meters	✓	✓	✓	✓	✓	✓	✓	✓	✓
Smart appliances	✓	×	×	×	×	×	×	×	×
Smart agricultural control panels	×	×	×	✓	×	×	×	×	×

4.5. Upcoming technologies

Various upcoming technologies are being experimented with which may be used in the IoT environment. A few of the technologies which are under development are mentioned below:

- **Narrowband IoT (NB-IoT)**: It is a standards-based low-power wide area (LPWA) technology developed to enable a wide range of new IoT devices and services. NB-IoT significantly improves the power dissipation of user devices, system capacity and spectrum efficiency, especially in deep coverage. It has a battery life of more than 10 years and can be used to support a wide range of use cases.
- **DASH7 Alliance Protocol (D7A)**: It is an open source wireless sensor and actuator network protocol, which operates in the 433 MHz, 868 MHz and 915 MHz unlicensed ISM band/SRD band. DASH7 provides

multi-year battery life, a range of up to 2 km, low latency for connecting with moving things, a very small open source protocol stack, AES 128-bit shared key encryption support, and data transfer of up to 167 kbit/s. The DASH7 Alliance Protocol is the name of the technology promoted by the non-profit consortium called the DASH7 Alliance.

- **Li-Fi**: It is a bidirectional, high-speed and fully networked wireless communication technology similar to Wi-Fi. The term was coined by Harald Haas and is a form of visible light communication and a subset of optical wireless communications (OWC). It could be a complement of RF communication (Wi-Fi or cellular networks), or even a replacement in the context of data broadcasting. It is wire and UV visible-light communication or infrared and near UV instead of RF spectrum, part of OWC technology, which carries much more information and has been proposed as a solution to the RF bandwidth limitations.

4.6. Conclusion

- Wi-Fi, Bluetooth, Cellular, ZigBee, Z-Wave, Wi-Sun, 6LoWPAN, Sigfox, Lora WAN, PLC, etc.—all these communication technologies have their strengths and weaknesses. Potential issues with security, costs, access, and the considerations outlined above should be considered in order to choose the best technology for the applications.
- Low-power RF is the most effective communication technology that would offer connectivity to a plethora of applications. The main reasons for this include (but are not limited to) low operating cost, less power dissipation, long range (if sub-GHz frequency bands are used), good coverage and penetration.
- As seen above, there are various wired and wireless technologies which are available which can be used for various applications, but there's room for all of them. A sufficient number of bands are available for IoT communication as of now, but as the number of smart devices using RF are going to be significantly large in number soon, India would be better off by allocating wider RF operating bands.

As per the analysis done by the India Smart Grid Forum (ISGF) along with other stakeholders for the telecommunication engineering sector (TEC), it is recommended that a frequency band of 10–12MHz may be required for low-power RF devices, with the assumption that the number of connected devices will be 6.58 devices per person by 2020 and 50–60% of the M2M/IoT/IoE devices will be using the sub-GHz frequency band.[19]

[19] M2M enablement in power sector: Spectrum requirements for PLC and low power RF communications, Telecommunications Engineering Centre, November 2015

5. Task III – Proliferation of smart products

This chapter estimates the present market size for each of the products so that proliferation projections can be developed to forecast the number of IoT devices and the standby power dissipation.

Note:

- The proliferation percentage for every smart product has been calculated and is estimated from the period starting from March 2017 till March 2030.
- Based upon our discussions with product manufacturers and depending upon the current market conditions, a penetration percentage for the entire forecast horizon for each product has been assumed. The penetration percentage envisages the penetration of 'smart' products as a percentage of overall products.
- The year 2024 has been considered as a turning point for the incoming smart technologies and will serve as the inflection point. The proliferation of products will follow a conservative approach before 2024. But after 2024, certain factors such as a decline in the cost of technologies involved, easy availability of smart products and ongoing government initiatives and programmes will push the smart product market. Hence, the IoT market will grow at an accelerated pace from 2024 onwards.
- Comprehensive excel models have been developed to project the growth and penetration of smart products as well as to calculate the impact of IoT devices on energy efficiency.
- The growth rate estimated relies on several external factors like market drivers, policymakers, even distribution and availability of the product in the market. Hence, it is better to estimate the projected growth rate in terms of three different scenarios – optimistic, moderate and pessimistic.
  - The **optimistic scenario** considers the highest growth rate of normal products under a proposed IoT solution (a product without any IoT feature) as most of the dependent factors are in favour of the overall demand.
  - The **moderate scenario** considers the business as usual (BAU) and, hence, the growth rate estimated has been kept as of past trends and current conditions.
  - The **pessimistic scenario** considers the unfavourable growth conditions; hence, a reduced growth percentage is used in this case.

5.1. Smart bulbs

As of 2017, the smart bulb market is at a nascent stage because of the high costs involved. Hence, the current penetration for smart bulbs has been considered to be zero. The market would slowly increase as costs decline and technologies mature. The penetration rate would increase to 3% in 2021 and after 2021, due to low costs and easily available technology, the penetration of smart bulbs will reach around 50% in 2030.

Table 21: Present market size and growth rate of bulbs

Total no. of LED bulbs in March 2017 (million) (approx.)	**282[20]**
CAGR for the bulbs till 2030 (%)	10[21]%

The inflection point chosen for bulbs is 2021 as according to some manufacturers, low-cost smart bulbs will enter the market in the next 3–4 years and they will completely transform the Indian smart bulb market scenario.

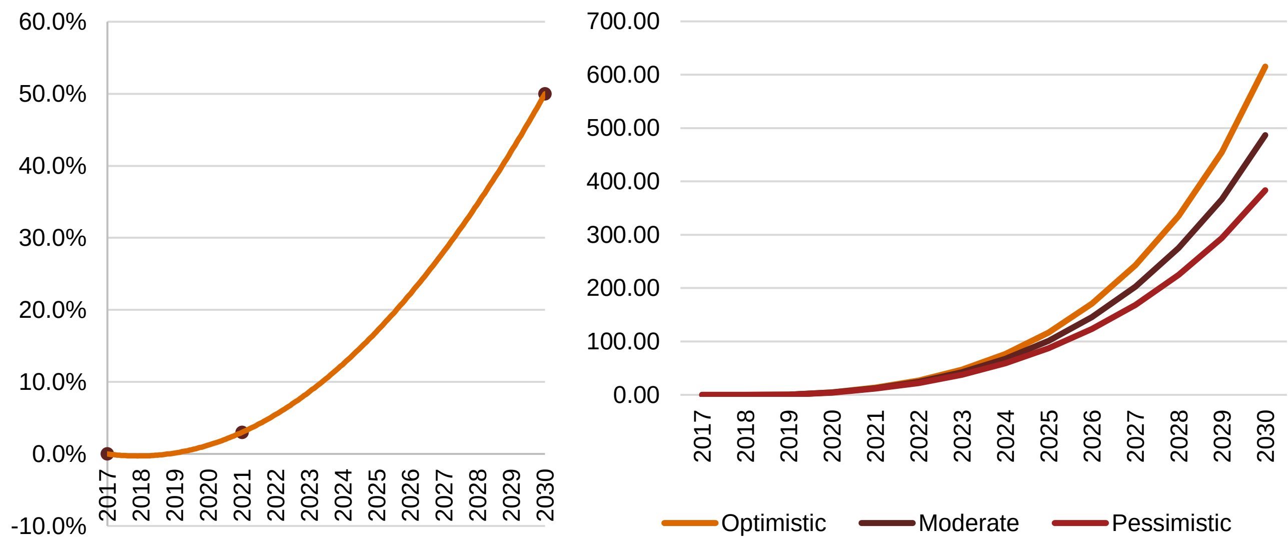
[20] SSEF–PwC study
[21] SSEF–PwC study

Table 22: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR for the bulbs till 2030 (%)	12%	10%	8%
Projected number of bulbs till 2030 (million)	1230.5	973.5	766.9
Projected number of smart bulbs till 2030 (million)	**615.25**	**486.77**	**383.47**

The resulting forecast for smart bulbs is shown in the figure below. It has been estimated that the number of smart bulbs in use will grow from the current negligible base to 615.25 million under the optimistic scenario, 486.77 million under the moderate scenario and 383.47 million under the pessimistic scenario.

Figure 11: Penetration curve for smart bulbs and number of smart bulbs (in million)



5.2. Smart street lights

Under the Indian government's SLNP, conventional street lights are to be replaced with group controlled smart and energy-efficient LED street lights. As of 2017, 2.7 million conventional street lights have already been replaced with smart ones. Also, there is an increased deployment of smart poles and street lights due to the smart city and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) missions. Hence, the current penetration for the smart street lights has been estimated to be 9%. It will steadily increase to 85% in 2024 and till 2030, almost all street lights would become connected; therefore, the penetration percentage has been assumed to be 95% in 2030.

Table 23: Present market size and growth rate of street lights

Total number of street lights in March, 2017 (in million) (approx.)	**42.6[22]**

Under the SLNP, the replacement of 3.5 crore conventional street lights will result in savings of 9,000 million units annually. The total cost savings of municipalities every year will be 5,500 crore INR.

Source: PIB, Government of India

[22] Based on CEA consumption and 60 W lights operating for 11 hours.

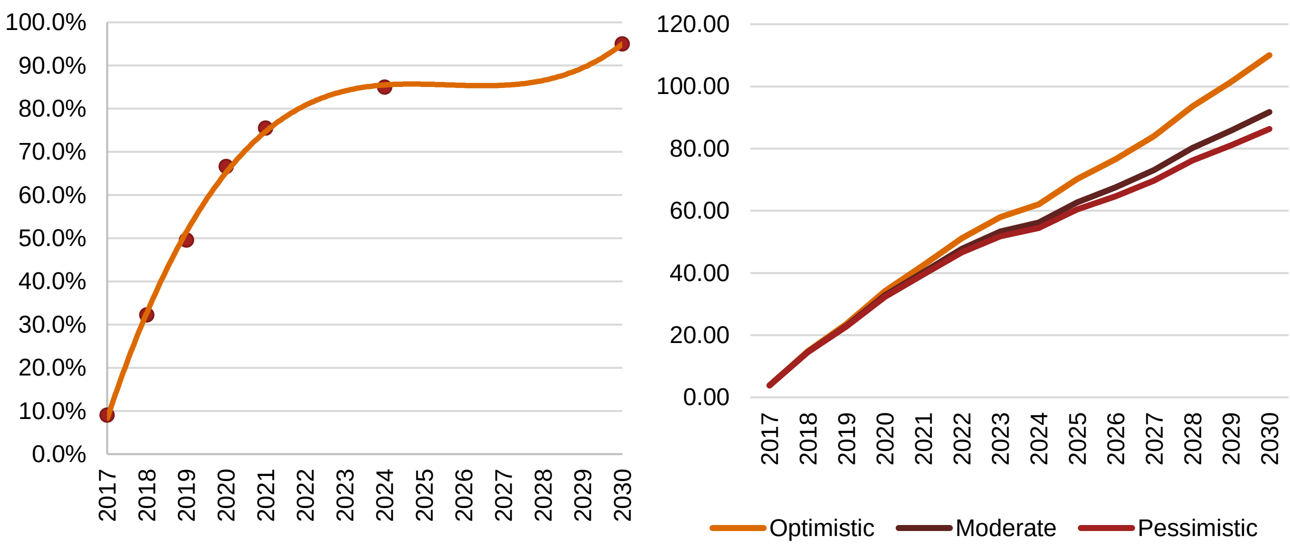
CAGR for the street lights till 2030 (%)	7%[23]

Table 24: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR for street lights till 2030 (%)	8%	7%	6%
Projected number of street lights till 2030 (million)	115.9	96.6	90.9
Projected number of smart street lights till 2030 (million)	**110.06**	**91.77**	**86.32**

The resulting forecast for smart street lights is shown in the figure below. It has been estimated that the number of smart street lights in use will grow from the current base of 3.84 million to 110.06 million under the optimistic scenario, 91.77 million under the moderate scenario and 86.32 million under the pessimistic scenario.

Figure 12: Penetration curve for smart street lights and number of smart street lights (in million)



5.3. Smart agricultural control panels

Considering 3 lakh control panels to be smart in 2017, the current penetration would be 5.3%. It is estimated that the penetration rates would jump to 8% by 2018 due to many agriculture DSM projects carried out by the EESL. These projects would educate customers about the benefits of smart panels. The penetration rate will sit at around 25% in 2024 and will rise to 75% in 2030 because of the availability of low-cost control panels and technology maturation. The number of smart control panels will rise from 0.45 million to 30.7 million till 2030.

According to TEDDY 2014-2015, in 2011–2012, the number of agricultural pumps was 23.64 million and according to the IPMA, the CAGR for agricultural pumps is 7.5%. Hence, the number of agricultural pumps in India in 2017 was 33.94 million. Now, only metered consumers can use starter control panels as the starter kit only allows metered connections. Therefore, the total number of starter control panels is estimated to be around 8.48 million in the present Indian market.

[23] CEA growth of public lighting demand

Table 25: Present market size and growth rate of agricultural control panels

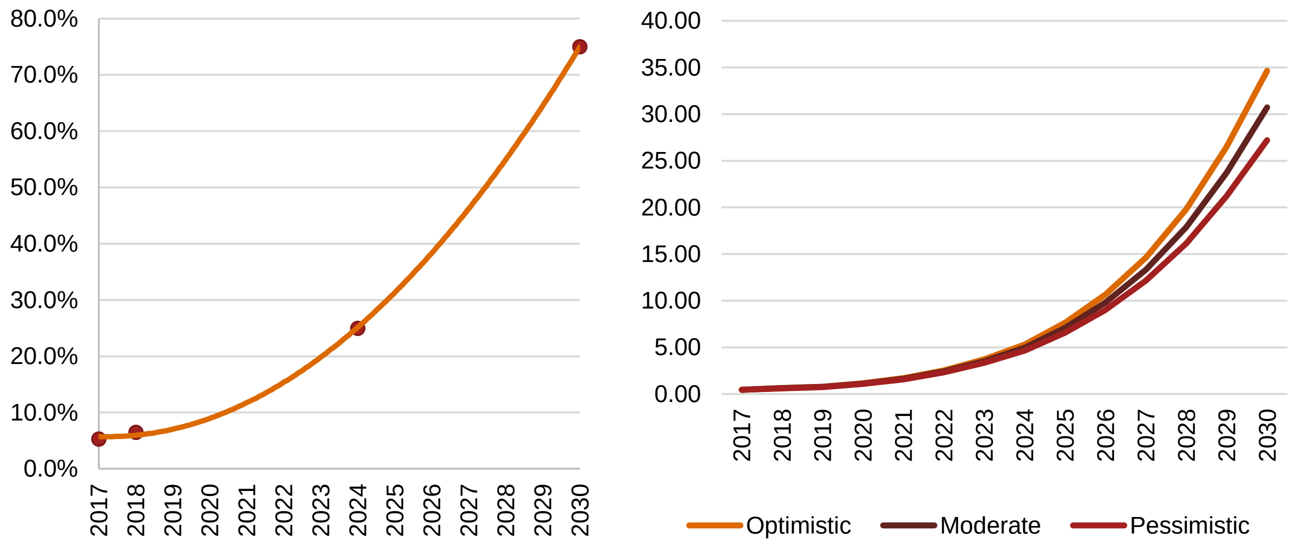
Number of agricultural pumps (in million)	**33.94**[24]
CAGR for agricultural pumps (%)	7.5%[25]
Proportion of metered consumers in India	25%
Total number of starter control panels in March 2017 (in million) (approx.)	**8.48**
CAGR of metered consumers (%)	5%

Table 26: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR for agricultural pumps till 2030 (%)	8.5%	7.5%	6.5%
Projected number of agricultural pump consumers till 2030 (in million)	98.0	86.9	77.0
Projected number of agricultural control panels till 2030 (in million)	46.20	40.96	36.28
Projected number of smart agricultural control panels till 2030 (in million)	**34.65**	**30.72**	**27.21**

The resulting forecast for agricultural smart control panels is shown in the figure below. It has been estimated that the number of smart control panels in use will grow from the current base of 0.45 million to 34.65 million under the optimistic scenario, 30.72 million under the moderate scenario and 27.21 million under the pessimistic scenario.

Figure 13: Penetration curve for smart control panels and number of smart control panels (in million)



5.4. Smart sockets

The inventory of the sockets as of March 2017 was estimated by assuming the number of sockets in each household and number of electrified households (and using electricity as the main source of lighting). To bring homogeneity to the estimation, assumptions for urban and rural households were made separately.

[24] According to TEDDY 2014-15, the figure for 2011–12 is 23.64 million.
[25] IPMA presentation during the National Workshop on Agricultural Demand Side Management (AgDSM), Jan 2016

Table 27: Number of households in India

Year	2001	2011
Total number of households[26] (million)	193.58	246.69
Electrified households[27] (%)	66.76%	78.14%
Growth rate of total households (in 10 years) (%)	27.44%	
CAGR (till 2011) (%)	2.45%	

The growth rate of the Indian population has slowed down considerably in the last decade. Hence, the CAGR for households after 2011 and till March 2017 has been steady at 1.4%.[28] In 2011, 78.14% of houses were electrified but only 67.24% households used electricity as their main source of lighting.

Therefore, for the period till March, 2017, the number of households will be:

Table 28: Forecasted number of households in India in 2017

Year	2017
Total number of households (in million) [forecasted]	268.15
Electrified households[29] (%)	93.37%
Household using electricity as their main source of lighting (%) [assumption]	83.00%
Total number of households using electricity as their main source of lighting (in million)	222.56
Total number of rural households[30] using electricity as their main source of lighting (in million)	152.68
Total number of urban households using electricity as their main source of lighting (million)	69.88

For the rural sector:

The total number of rural households using electricity as their main source of lighting is 152.68 million.

Table 29: Total number of sockets for rural households

Number of rooms in a household	Sockets available per household	Percentage of households having corresponding number of rooms[31]	Number of households with corresponding number of rooms (in million)	Total number of sockets (in million)
No exclusive room	0	0.7	1.07	0
1 room	2	34.9	53.28	106.57
2 rooms	4	26.5	40.46	161.84
3 rooms	6	18.3	27.94	167.64
4 rooms	8	10.8	16.5	131.92

[26] http://censusindia.gov.in/Census_Data_2001/States_at_glance/State_Links/07_del.pdf
[27] https://en.wikipedia.org/wiki/Indian_states_ranking_by_households_having_electricity
[28] https://tradingeconomics.com/india/population-growth-annual-percent-wb-data.html
[29] https://en.wikipedia.org/wiki/Indian_states_ranking_by_households_having_electricity
[30] http://www.moef.nic.in/downloads/public-information/Residentialpowerconsumption.pdf
[31] http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20314.pdf

Number of rooms in a household	Sockets available per household	Percentage of households having corresponding number of rooms[31]	Number of households with corresponding number of rooms (in million)	Total number of sockets (in million)
5 rooms	10	4.2	6.41	64.12
6 rooms and above	12	4.6	7.02	84.28
Total			**152.68**	**716.38**

For the urban sector:

The total number of urban households using electricity as their main source of lighting is 69.88 million.

Table 30: Total number of sockets for urban households

Number of rooms in a household	Sockets available per household	Percentage of households having corresponding number of rooms	Number of households with corresponding number of rooms (in million)	Total number of sockets (in million)
No exclusive room	0	0.9	0.63	0
1 room	3	38.3	26.76	80.3
2 rooms	5	27.0	18.87	94.34
3 rooms	7	17.9	12.51	87.56
4 rooms	9	8.9	6.22	56.00
5 rooms	11	2.9	2.02	22.3
6 rooms and above	13	4.1	2.86	37.25
Total			**69.88**	**377**

Table 31: Total number of sockets in India in 2017

Total number of sockets in March 2017 (in million) (approx.)	1,094.12

The current penetration rate for smart sockets is negligible as the smart socket market is in the very early stages in India. But socket manufacturers are expected to introduce low-cost smart sockets in the near future which will be easy to install and control, and this will drive the smart socket market. Hence, penetration is expected to reach at 15% in 2024 and 60% in 2030.

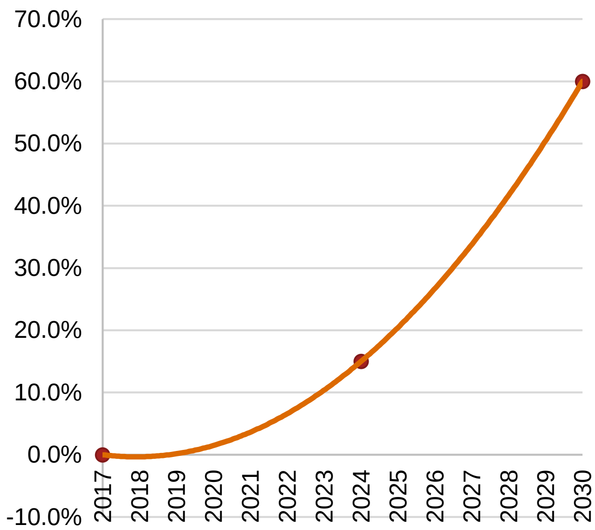
The total number of sockets will grow from 1,094.12 million in 2017 to 1,261.3 million in 2030 and the number of smart sockets will rise from 0 to 756.8 million by 2030.

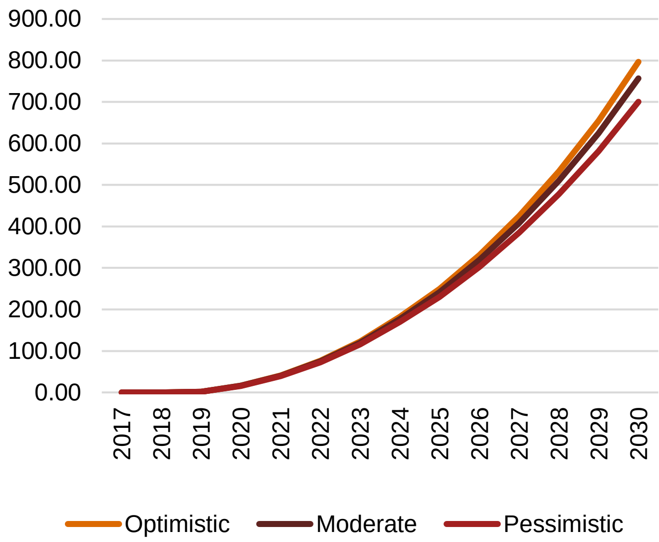
Table 32: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR till 2030 (%)	1.5%	1.1%	0.5%
Projected number of sockets till 2030 (in million)	1,327.8	1,261.3	1,167.4
Projected number of smart sockets till 2030 (in million)	**796.66**	**756.8**	**700.45**

The resulting forecast for smart sockets is shown in the figure below. It has been estimated that the number of smart sockets in use will grow from the current negligible base to 796.66 million under the optimistic scenario, 756.8 million under the moderate scenario and 700.45 million under the pessimistic scenario.

Figure 14: Penetration curve for smart sockets and number of smart sockets (in million)





5.5. Smart meters

Considering around 25 lakh meters to be smart in 2017, the current penetration is 1.1%. It is estimated to jump to 20% by 2018[32]. It will grow to 85% in 2024[33] and will reach almost 100% in 2030.

According to Mr. Piyush Goel, former Minister of State (Independent Charge) for Power, Coal and New & Renewable Energy, 'India is close to implementing smart meters and at prices that will not pinch the pockets of consumers.'

He also added, 'My own intention is that in the next 5–6 years, India should be 100% smart. We should look at a smart meter in every home and every installation.'

Table 33: Present market size and growth rate of meters

Total number of electricity connections in India[34] (in million)	**250**
Total number of unmetered connections (in million)	25
Total number of metered connections in March 2017 (in million) (approx.)	**225**
CAGR (%)	7%[35]

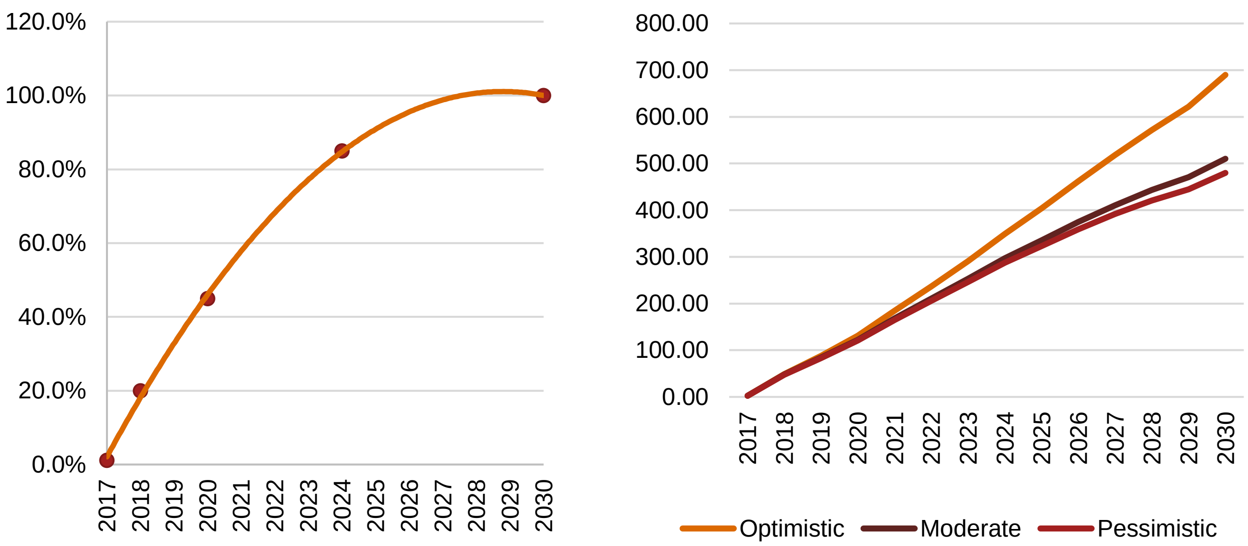
[32] Considering 20% of metered consumers in India consume >500 units per month and the MOP directive (http://powermin.nic.in/sites/default/files/webform/notices/Strategy_for_Rollout_of_Advanced_metering_infrastructure.pdf)
[33] Statement by Minister of Power regarding 100% smart meter penetration in the next 5 to 6 years (http://www.thehindubusinessline.com/specials/clean-tech/we-should-look-at-a-smart-meter-in-every-home-piyush-goyal/article8245384.ece)
[34] http://www.indiasmartgrid.org/reports/ISGF%20White%20Paper%20on%20AMI%20Roll-Out%20Strategy%20for%20India.pdf
[35] Frost and Sullivan – Energy and power systems practice – South Asia, Middle East and North Africa specifies a CAGR of around 11%, but we are considering a conservative approach.

Table 34: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR till 2030 (%)	9%	7%	6%
Projected number of metered consumers till 2030 (in million)	689.8	510.2	479.9
Projected number of smart meters till 2030 (in million)	**689.8**	**510.2**	**479.9**

The resulting forecast for smart meters is shown in the figure below. It has been estimated that the number of smart meters in use will grow from the current estimated base of 2.5 million to 689.8 million under the optimistic scenario, 510.2 million under the moderate scenario and 479.9 million under the pessimistic scenario.

Figure 15: Penetration curve for smart meters and number of smart meters (in million)



5.6. Smart AC/thermostat

The total number of ACs in 2017 is estimated at 37.268 million units, which is growing at a rate of 10% annually. The penetration of smart ACs was found to be around 0.7% [36]among the total number of units installed. By 2024, smart AC penetration will increase to 10% as consumers will become aware of the benefits of smart ACs, leading to the eventual phasing out of conventional ACs. By 2030, the penetration is expected to reach around 45%. The number of smart ACs will rise from 0.25 million to 57.9 million till 2030.

Table 35: Present market size and growth rate of ACs

Total number of ACs in March 2017 (in million) (approx.)	37.268[37]
CAGR (%)	10%[38]

[36] Number for Videocon in Motlilal Oswal Report --
(http://www.motilaloswalgroup.com/AnalystVideo/Pdf/1619522538ENGG-20170424- MOSL-SU- PG054.pdf)
[37] http://www.livemint.com/Industry/VzfJdFbXDpxINbQvpsUJpM/After-a-cool-spell-AC-market-heats-up.html
[38] https://www.techsciresearch.com/news/422-india-air-conditioners-market-to-witness-growth-of-over-10-until-2020.html

According to the Consumer Electronics and Appliances Manufacturers Association (CEAMA), India sold about 3.3 million AC units in the fiscal 2013–14 period. Currently, at 28 million ACs in the country, their penetration rate is about 3-3.5%. The AC numbers would reach 45–50 million in the next two to three years.

According to a recently published TechSci Research report 'India air conditioners market forecast and opportunities, 2020', the country's AC market is projected to grow at a CAGR of over 10% during 2015–20.

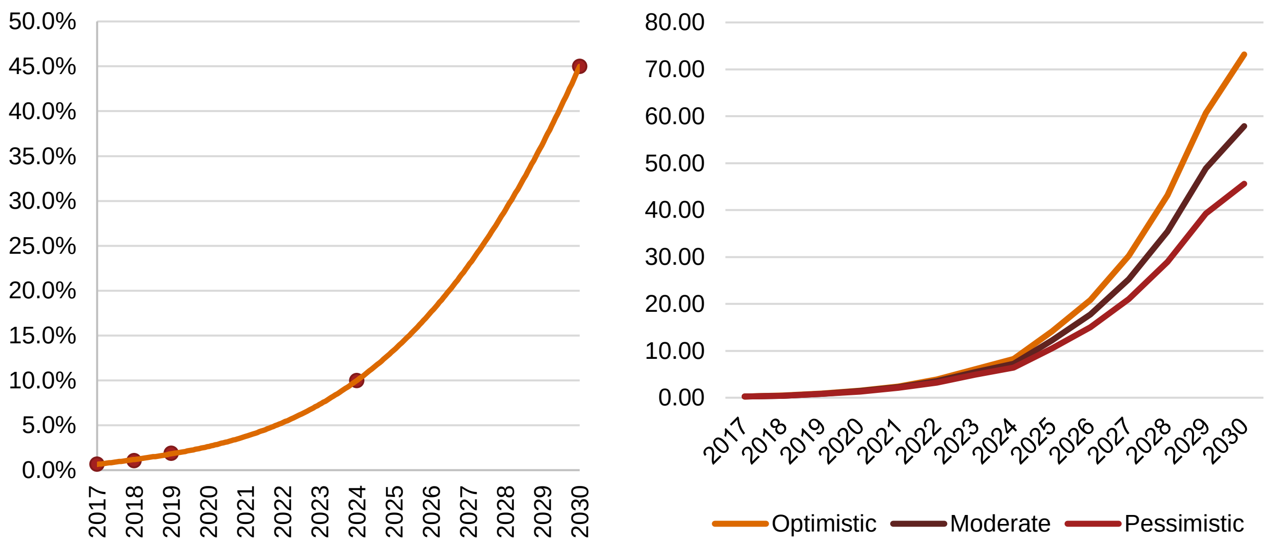
The total number of ACs will grow from 37.268 million in 2017 to 128.7 million in 2030 at a CAGR of 10%.

Table 36: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR till 2030 (%)	12%	10%	8%
Projected number of ACs till 2030 (in million)	162.6	128.7	101.4
Projected number of smart ACs till 2030 (in million)	**73.18**	**57.90**	**45.61**

The resulting forecast for smart ACs is shown in the figure below. It has been estimated that the number of smart ACs in use will grow from the current estimated base of 0.25 million to 73.18 million under an optimistic scenario, 57.9 million under a moderate scenario and 45.61 million under a pessimistic scenario.

Figure 16: Penetration curve for smart ACs and number of smart ACs (in million)



5.7. Smart geysers

The share of smart geysers in 2017 is negligible and is assumed to be zero as the market is in its early stages. However, the penetration will slowly reach around 3% by 2024 and will increase to 25% by 2030. The number of smart geysers will rise from zero to 1.54 million till 2030.

Table 37: Present market size and growth rate of geysers

Total number of Geysers in March 2017 (in million) (approx.)	2.4[39]
CAGR (%)	7.5[40]%

39 Global market "Electric Water Heater Market Size - 2016-2024" report and https://www.gminsights.com/industry-analysis/electric-water- heater-market
40 Global market "Electric Water Heater Market Size - 2016-2024" report and https://www.gminsights.com/industry-analysis/electric-water- heater-market

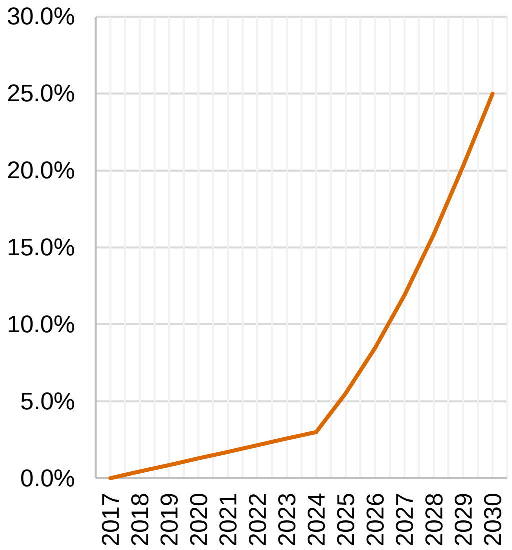
The total number of geysers will grow from 2.4 million in 2017 to 6.1 million in 2030 at a CAGR of 7.5%.

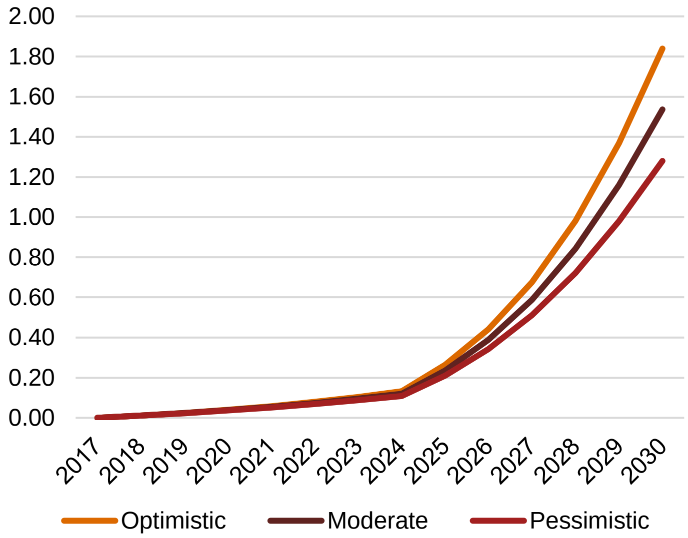
Table 38: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR till 2030 (%)	9%	7.5%	6%
Projected number of geysers till 2030 (in million)	7.4	6.1	5.1
Projected number of smart geysers till 2030 (in million)	**1.84**	**1.54**	**1.28**

The resulting forecast for smart geysers is shown in the figure below. It has been estimated that the number of smart geysers in use will grow from the current negligible base to 1.84 million under an optimistic scenario, 1.54 million under a moderate scenario and 1.28 million under a pessimistic scenario.

Figure 17: Penetration curve of smart geysers and number of smart geysers (in million)





5.8. Smart refrigerators

Currently, the penetration of smart refrigerators is negligible and is assumed to be zero as the market is very nascent. The penetration will slowly increase to 3% by 2024 and 25% by 2030, and the number of smart refrigerators will rise from zero to 105.33 million by 2030.

Table 39: Present market size and growth rate of refrigerators

Total number of refrigerators in March 2017 (in million) (approx.)	91.125[41]
CAGR (%)	13%[42]

[41] Around 9 million fridges sold in India in 2016 ((http://economictimes.indiatimes.com/industry/cons-products/durables/bosch-to- foray-into- indian-refrigerator- market/articleshow/51812667.cms) and also MOEF report projects 99 million
[42] India Refrigerator Market Outlook, 2021 (16%) and IBEF - https://www.ibef.org/download/Consumer-Durables-January-2016.pdf (10%)

According to Gunjan Srivastava, MD and CEO of BSH Household Appliances Manufacturing, 'At present, the total size of refrigerator market is around 9 million units annually, out of which 2.2 million is from the double door segment'.

According to Indian Brand Equity Foundation (IBEF), 'The estimated market size for refrigerators in India is estimated at 1.45 billion USD in 2015. And the refrigerator segment is expected to grow at 10% from 2014 to 2020'.

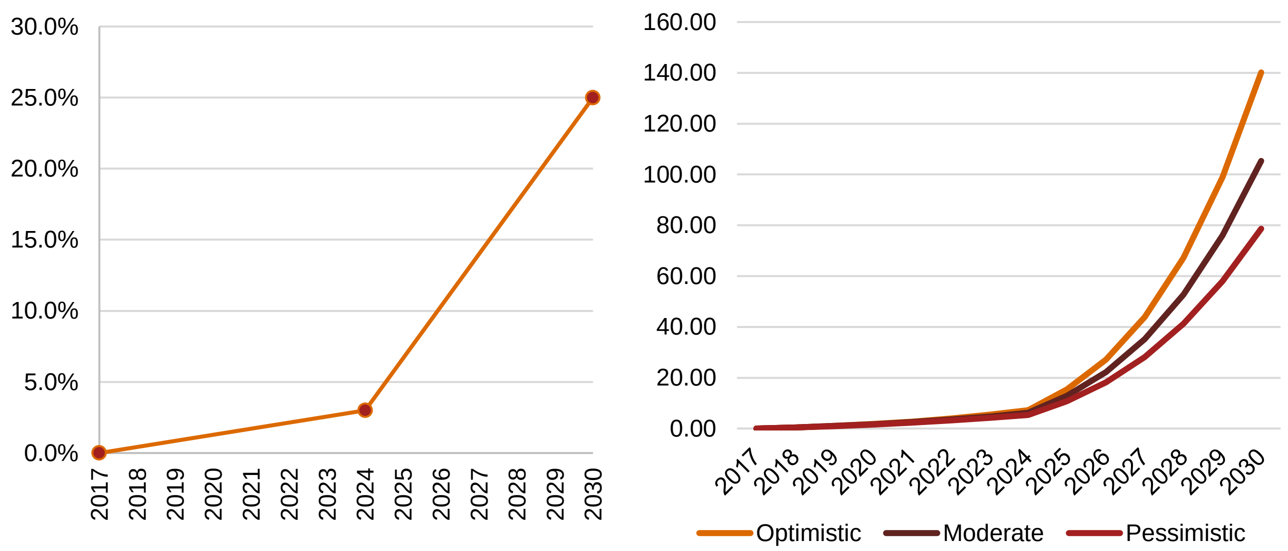
The total number of refrigerators will grow from 91.125 million in 2017 to 421.3 million in 2030 at a CAGR of 13%.

Table 40: Scenario analysis

Possible scenarios	Optimistic	Moderate	Pessimistic
CAGR till 2030 (%)	15%	13%	10%
Projected number of refrigerators till 2030 (in million)	560.7	421.3	314.6
Projected number of smart refrigerators till 2030 (in million)	**140.17**	**105.33**	**78.65**

The resulting forecast for the smart refrigerators is shown in the figure below. It has been estimated that the number of smart refrigerators in use will grow from the current negligible base to 140.17 million under an optimistic scenario, 105.33 million under a moderate scenario and 78.65 million under a pessimistic scenario.

Figure 18: Penetration curve for smart refrigerators and number of smart refrigerators (in million)



5.9. Smart televisions

The total number of TVs in 2017 is estimated at 195 million units. The share of smart TVs is 20% in the 19 million new TVs added in 2017. Hence, current penetration of smart TVs is estimated to be 2.9%, which will increase to 25% by 2024 as conventional TVs get phased out and will reach around 80% by 2030. The number of smart TVs will rise from 5.56 million to 282.37 million by 2030.

Table 41: Present market size and growth rate of TVs

Total number of TVs in March 2017 (in million) (approx.)	**195[43]**
CAGR (%)	5%[44]

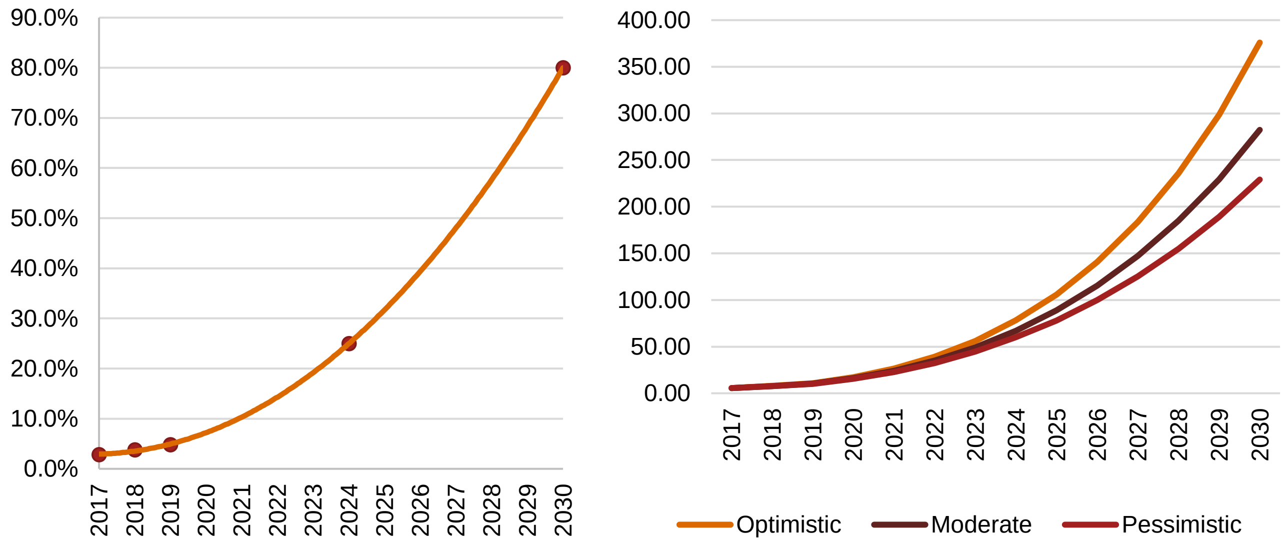
The total number of TVs will grow from 195 million in 2017 to 353 million in 2030 at a CAGR of 5%.

Table 42: Scenario analysis

Possible scenarios	**Optimistic**	**Moderate**	**Pessimistic**
CAGR till 2030 (%)	7%	5%	3%
Projected number of TVs till 2030 (in million)	469.9	353.0	286.4
Projected number of smart TVs till 2030 (in million)	**375.94**	**282.37**	**229.09**

The resulting forecast for smart TVs is shown in the figure below. It has been estimated that the number of smart TVs in use will grow from the current estimated base of 5.56 million to 375.94 million under an optimistic scenario, 282.37 million under a moderate scenario and 229.09 million under a pessimistic scenario.

Figure 19: Penetration curve of smart TVs and the number of smart TVs (in million)



5.10. Home and building automation

According to the global smart home automation system market study, the CAGR for smart home solutions is around 5%. It is, therefore, being considered as a moderate scenario under which the growth is most likely to occur. The optimistic percentage has been estimated to be around 8% and pessimistic to be 3%. The present market size has been gauged to be of 8,800 crore INR (the market viable for smart home automation systems); hence, by taking one automation system average cost to be 30,000 INR and only 5% of the viable market has smart systems installed, the total number of smart systems in 2017 is estimated to be 0.15 million units.

43 MoEF report
Malvania, U. (3 March 2017). Rural India has 17% more homes with TVs than cities. The Economic Times. Retrieved from http://www.business-standard.com/article/economy-policy/rural-india-has-17-more-homes-with-tvs-than-cities-117030300023_1.html (last accessed on XXX)
44 MoEF report – Residential Energy Consumption

Table 43: Present market size and growth rate of smart hubs

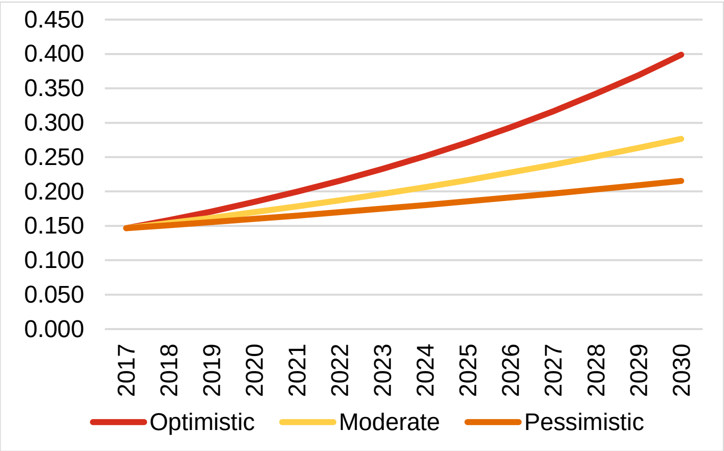
Total number of smart home automation systems in 2017 (in million) (approx.)	**0.15**
CAGR (%)	5%[45]

Table 44: Scenario analysis

Possible scenarios	**Optimistic**	**Moderate**	**Pessimistic**
CAGR till 2030 (%)	8%	5%	3%
Projected number of smart home automation systems till 2030 (in million)	0.4	0.28	0.21

The resulting forecast for home and building automation systems is shown in the figure below. It has been estimated that the number of smart systems in use will grow from the current estimated base of 0.147 million to 0.4 million under an optimistic scenario, 0.28 million under a moderate scenario and 0.21 million under a pessimistic scenario.

Figure 20: Number of smart home hubs (in million)



45 Global Smart Home Hub Market – Strategic Assessment and Forecast 2017–2022.

6. Task IV – Impact of IoT applications on energy consumption

The approximate market size of proposed IoT smart products has been estimated till 2030, considering 2024 as the inflection point. This chapter has been categorised into two sections. The first section attempts to estimate standby power from the expected proliferation of IoT solutions and will project the difference in standby dissipation due to use communication technologies dissipating maximum and minimum standby power. It also calculates the energy efficiency potential from employing suitable communication technology. The second section estimates the energy efficiency potential from the adoption of smart features based on various user behavioural patterns and automation of products. Peak demand reduction due to the use of smart products has also been estimated wherever possible.

6.1. Net standby power dissipation

Most of the products use two or three different communication technologies, resulting in varying standby power. Net standby power dissipation, ranging over a period of 14 years starting from 2017 till 2030, has been estimated solution-wise. Additionally, the energy efficiency potential by employing the most suitable communication technologies based on standby power has been calculated.

6.1.1. Smart bulbs

As assumed in the previous section, the number of smart light bulbs is currently negligible. However, the number will grow to 615.25 million, 486.77 million and 383.47 million, considering optimistic, moderate and pessimistic scenarios respectively by 2030.

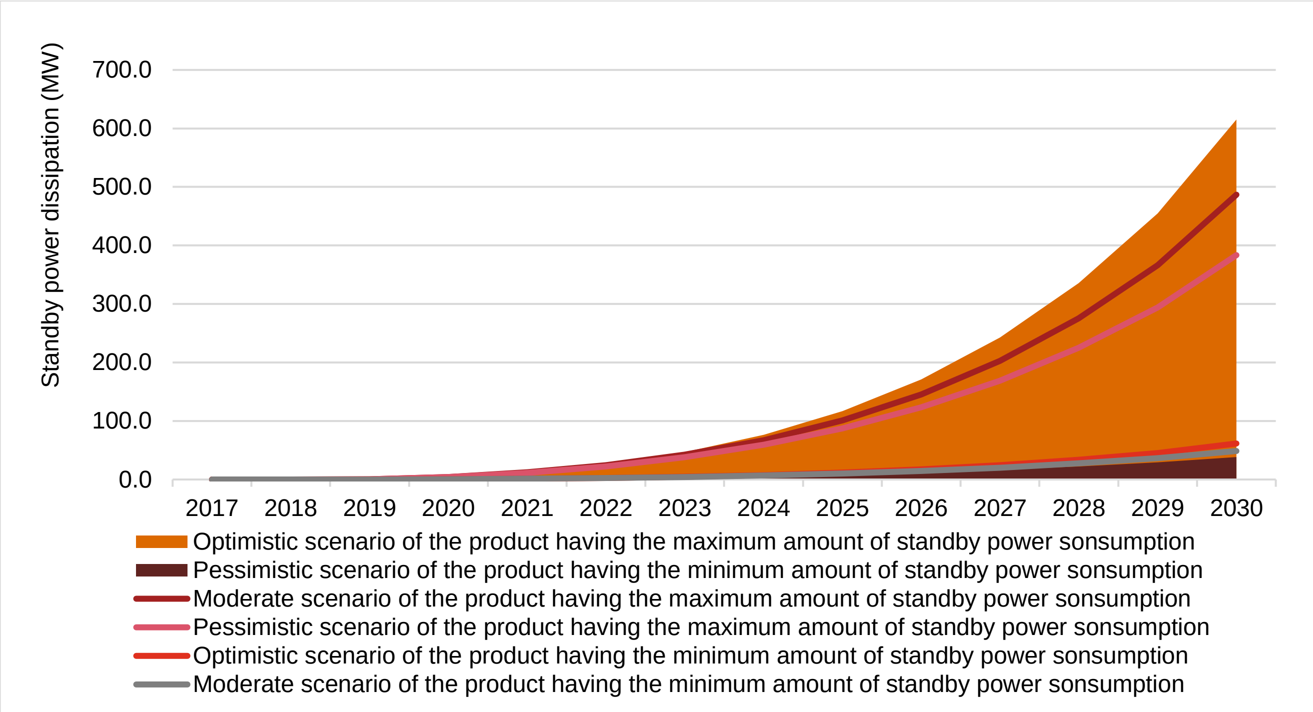
Three different combinations of communication technologies have been identified that are currently being used in the smart bulb space, as illustrated in Task I. Bulbs using Wi-Fi and ZigBee dissipate a net standby power of 0.4 W, whereas the other two products dissipate 0.5 and 1.0 W of standby power.

Table 45: Standby power forecast of smart bulbs

Sr. no.	Smart bulbs	Scenario	Net standby power (MW)	
			2017	2030
1	Bulb using Wi-Fi and ZigBee	Optimistic (12%)	0.0	61.5
		Moderate (10%)	0.0	48.7
		Pessimistic (8%)	0.0	38.3
2	Bulb using Wi-Fi	Optimistic (12%)	0.0	307.6
		Moderate (10%)	0.0	243.4
		Pessimistic (8%)	0.0	191.7
3	Bulb using Bluetooth	Optimistic (12%)	0.0	615.3
		Moderate (10%)	0.0	486.8
		Pessimistic (8%)	0.0	383.5

As estimated in the table above, bulbs using Bluetooth in an optimum scenario are dissipating maximum standby power, whereas bulbs using Wi-Fi and ZigBee in a pessimistic scenario are dissipating the minimum amount of standby power when compared with all the products in each and every scenario (as depicted in the graph below).

Figure 21: Standby power analysis



Hence, according to the above graph, the maximum savings in power dissipation because of using low-power communication technology—that is, Wi-Fi/ZigBee—is **577 MW**, as projected for 2030.

6.1.2. Smart street lights

As estimated in the Task III projection, the number of smart street lights will grow from 3.84 million to 110.6 million, 91.77 million and 86.32 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

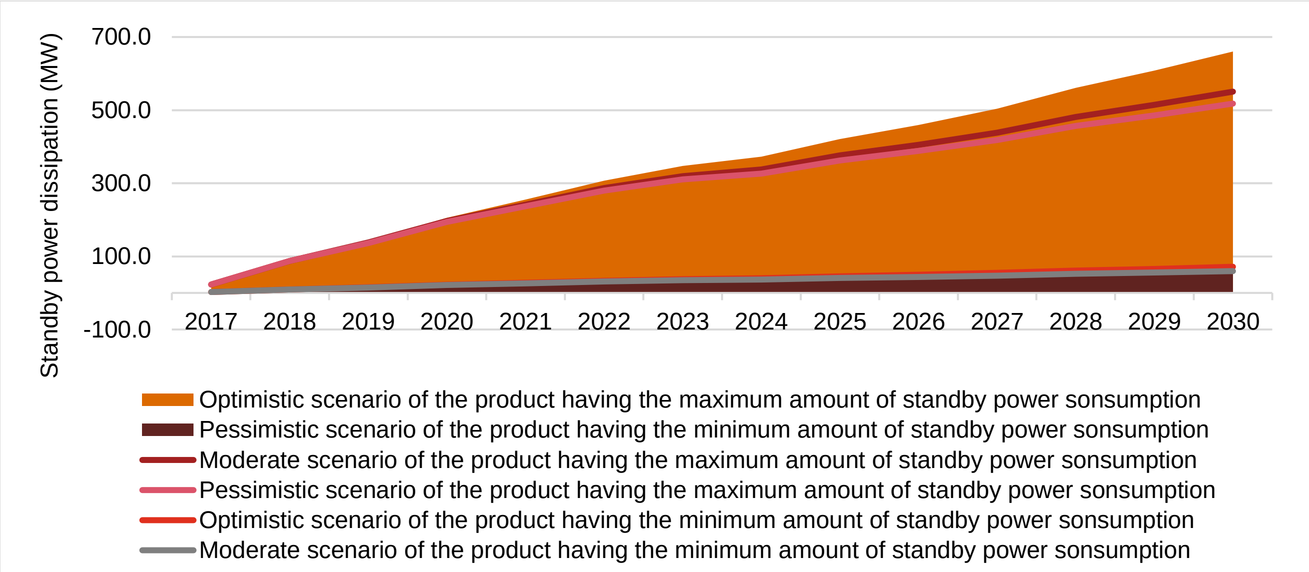
Three different communication technologies have been identified that are being used currently in the smart street light space (refer Task I). GSM/GPRS-based group controllers employ a feeder panel which dissipates net standby power of 5.0 W, whereas the other two products—that is, GSM/GPRS-based individual lamp controller and LR-WPAN based controller dissipate 6.0 and 0.65 W of standby power respectively.

Table 46: Standby power forecast of smart street lights

Sr. no.	Smart street lights	Scenario	Net standby power (MW)	
			2017	2030
1	GSM/GPRS-based group controller	Optimistic (8%)	19.2	550.3
		Moderate (7%)	19.2	458.8
		Pessimistic (6%)	19.2	431.6
2	GSM/GPRS-based individual lamp controller	Optimistic (8%)	23.0	660.4
		Moderate (7%)	23.0	550.6
		Pessimistic (6%)	23.0	517.9
3	LR-WPAN based controller	Optimistic (8%)	2.5	71.5
		Moderate (7%)	2.5	59.6
		Pessimistic (6%)	2.5	56.1

As estimated in the table above, a GSM/GPRS-based individual lamp controller in an optimum scenario dissipates the maximum amount of standby power, whereas a LR-WPAN based controller in a pessimistic scenario dissipates the minimum amount of standby power when compared with all the products in each and every scenario (as depicted in the graph below).

Figure 22: Standby power analysis



Hence, according to the above graph, the maximum savings in power dissipation because of using low-power communication technology—that is, RF—is **604.3 MW**, as projected for 2030.

6.1.3. Agricultural control panels

As estimated in the Task III projection, the number of smart control panels will grow from 0.45 million to 34.65 million, 30.72 million and 27.21 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

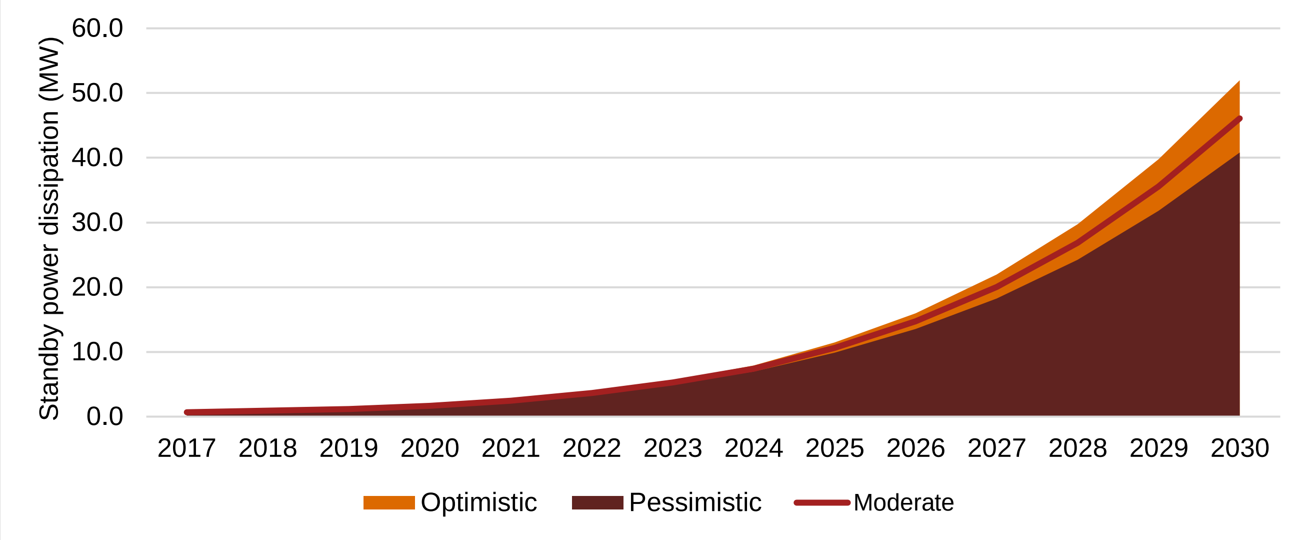
GSM has been identified as the only communication technology that is being used currently in the smart control panel space (refer Task I). The GSM-based mobile starter panel dissipates a net standby power of 1.5 W.

Table 47: Standby power forecast of smart agricultural control panels

Sr. no.	Smart control panels	Scenario	Net standby power (MW)	
			2017	2030
1	GSM-based mobile starter panel	Optimistic (8.5%)	0.7	52.0
		Moderate (7.5%)	0.7	46.1
		Pessimistic (6.5%)	0.7	40.8

As estimated in the table above, GSM-based mobile starter panels in an optimistic scenario dissipate the maximum amount of standby power, whereas the same in a pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 23: Standby power analysis



Hence, according to the above graph, the maximum estimated standby power dissipation because of smart control panels is **52.0 MW** and the minimum estimated standby power dissipation is **40.8 MW**, as projected for 2030.

6.1.4. Smart sockets

As estimated in the Task III projection, the number of smart sockets are presently negligible in the country. However, the number will grow to 796.66 million, 756.80 million and 700.45 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

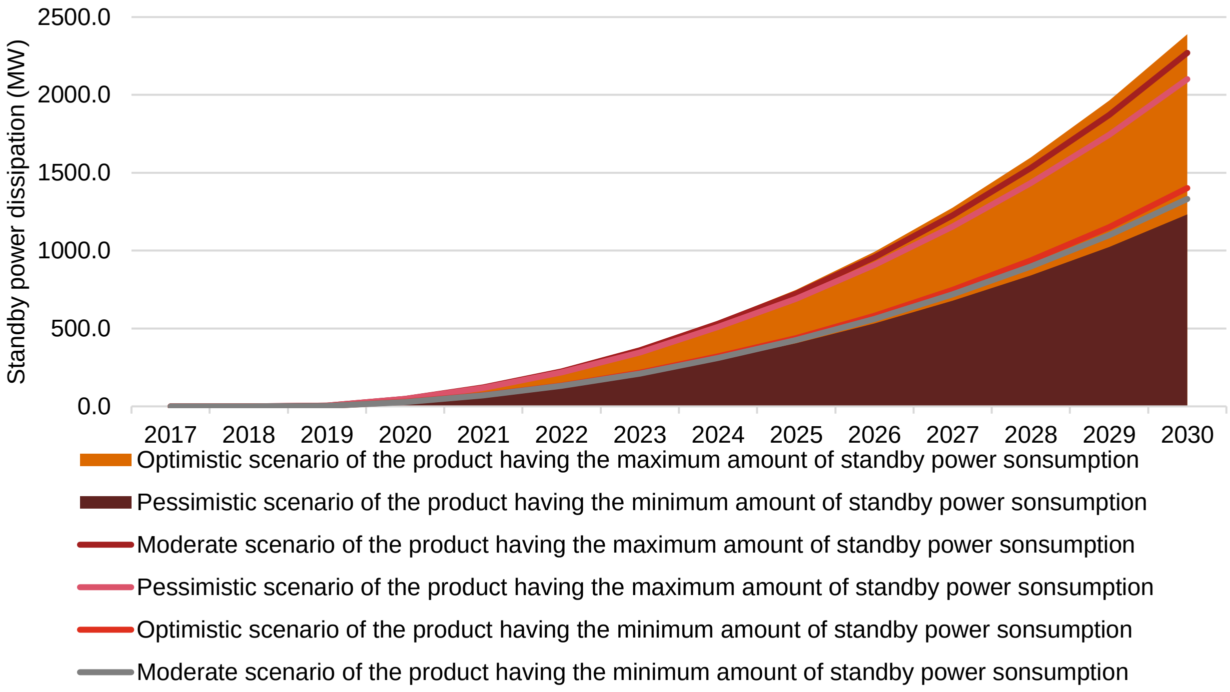
Two different communication technologies have been identified that are currently being used in the smart socket space as already illustrated in Task I. Wi-Fi based sockets dissipate a net standby power of 3.0 W, whereas GSM-based sockets dissipate 1.76 W of standby power.

Table 48: Standby power forecast of smart sockets

Sr. no.	Smart sockets	Scenario	Net standby power (MW)	
			2017	2030
1	Wi-Fi based socket	Optimistic (1.5%)	0.0	2390.0
		Moderate (1.1%)	0.0	2270.4
		Pessimistic (0.5%)	0.0	2101.3
2	GSM-based socket	Optimistic (1.5%)	0.0	1402.1
		Moderate (1.1%)	0.0	1332.0
		Pessimistic (0.5%)	0.0	1232.8

As estimated in the table above, Wi-Fi based sockets in an optimum scenario dissipate the maximum amount of standby power, whereas GSM-based sockets in a pessimistic scenario dissipate the minimum amount of standby power when compared with all the products in each and every scenario (as depicted in the graph below).

Figure 24: Standby power analysis



Hence, according to the above graph, the maximum savings in power dissipation because of using low-power communication technology—that is, GSM—is **1157.2 MW**, as projected for 2030.

6.1.5. Smart meters

As estimated in the Task III projection, the number of smart meters will grow from 2.50 million to 689.81 million, 510.18 million and 479.91 million, considering optimistic, moderate and pessimistic scenarios in that order by 2030.

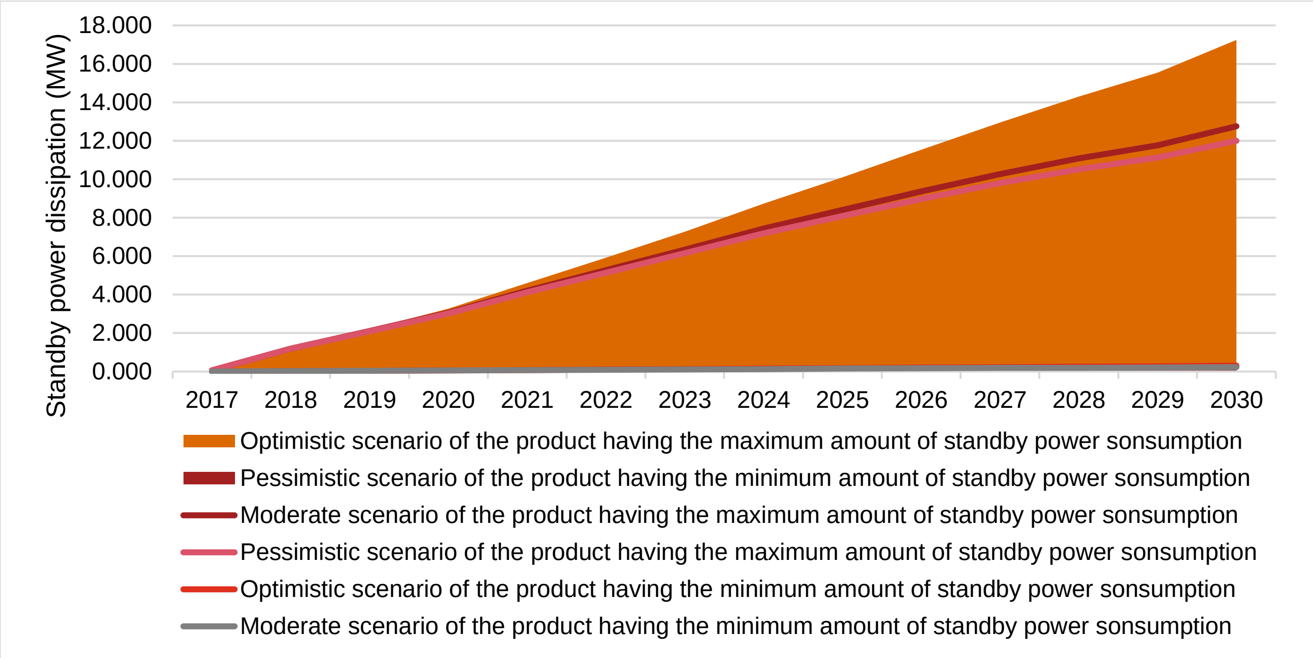
Three different communication technologies have been identified that are being used currently in the smart meter space (refer to Task I). Wi-Fi based meters employ a router, which dissipate a net standby power of 0.45 mille W, whereas the other two products—namely, LoRa-based meters and RF-based meters dissipate 9.24 mille W and 25 mille W of standby power.

Table 49: Standby power forecast of smart meters

Sr. no.	Smart meters	Scenario	Net standby power (MW)	
			2017	2030
1	Wi-Fi based meter	Optimistic (9%)	0.001	0.310
		Moderate (7%)	0.001	0.230
		Pessimistic (6%)	0.001	0.216
2	LoRa-based meter	Optimistic (9%)	0.023	6.374
		Moderate (7%)	0.023	4.714
		Pessimistic (6%)	0.023	4.434
3	RF-based meter	Optimistic (9%)	0.063	17.245
		Moderate (7%)	0.063	12.755
		Pessimistic (6%)	0.063	11.998

As estimated in the table above, RF-based meters in an optimum scenario dissipate the maximum amount of standby power, whereas Wi-Fi based meters in a pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 25: Standby power analysis



Hence, according to the above graph, the maximum savings in power dissipation because of using low-power communication technology—that is, Wi-Fi—is **17 MW**, as projected for 2030.

6.1.6. Smart ACs/thermostats

As estimated in the Task III projection, the number of smart ACs will grow from 0.25 million to 73.18 million, 57.90 million and 45.61 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

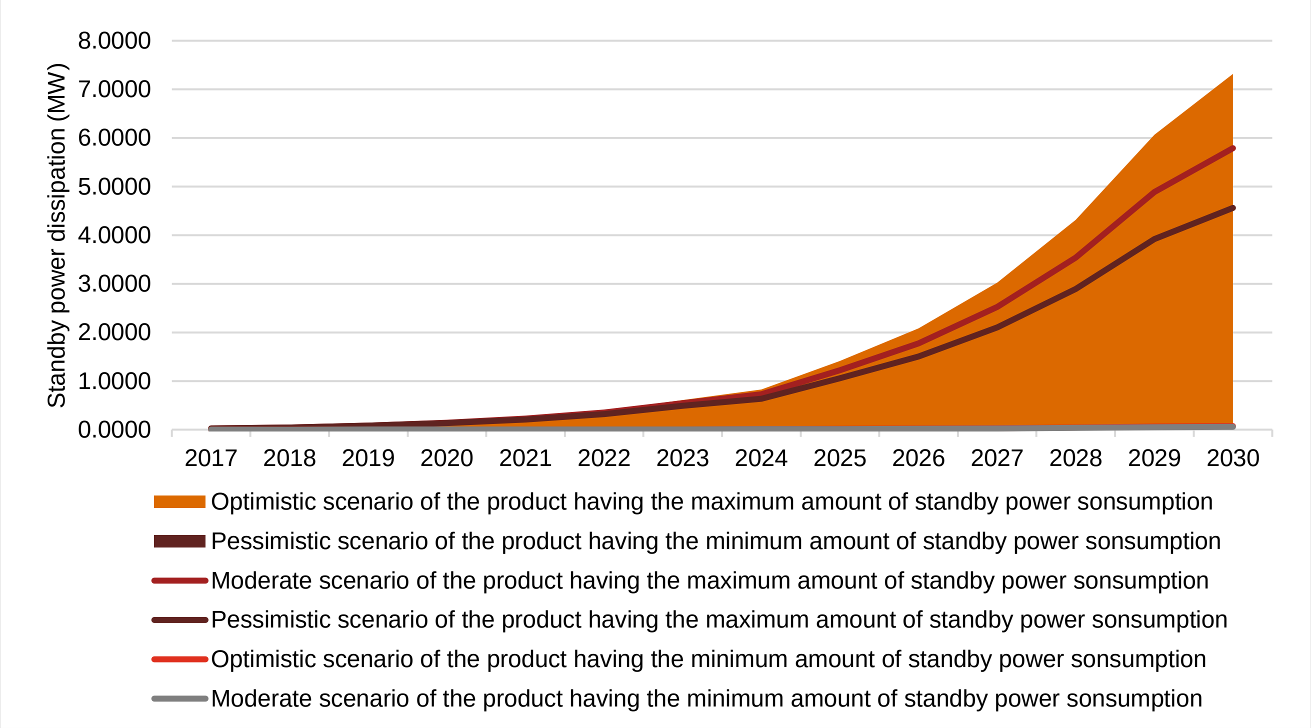
Two communication technologies have been identified that are being used currently in the smart AC space (refer Task I). Wi-Fi based ACs dissipate a net standby power of 0.1 W, whereas Wi-Fi AC + app, with cloud communication, dissipates 0.001 W of standby power.

Table 50: Standby power forecast of smart ACs

Sr. no.	Smart ACs	Scenario	Net standby power (MW)	
			2017	2030
1	Wi-Fi based AC	Optimistic (12%)	0.0254	7.3178
		Moderate (10%)	0.0254	5.7897
		Pessimistic (8%)	0.0254	4.5610
2	Wi-Fi AC + app	Optimistic (12%)	0.0003	0.0732
		Moderate (10%)	0.0003	0.0579
		Pessimistic (8%)	0.0003	0.0456

As estimated in the table above, Wi-Fi based ACs in an optimum scenario dissipate the maximum amount of standby power, whereas Wi-Fi AC + app in a pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 26: Standby power analysis



Hence, according to the above graph, the maximum savings in power dissipation because of using low-power communication technology—that is, Wi-Fi/RF—is **7.27 MW**, as projected for 2030.

6.1.7. Smart geysers

As estimated in the Task III projection, the number of smart geysers is almost negligible but will grow to 1.84 million, 1.54 million and 1.28 million considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

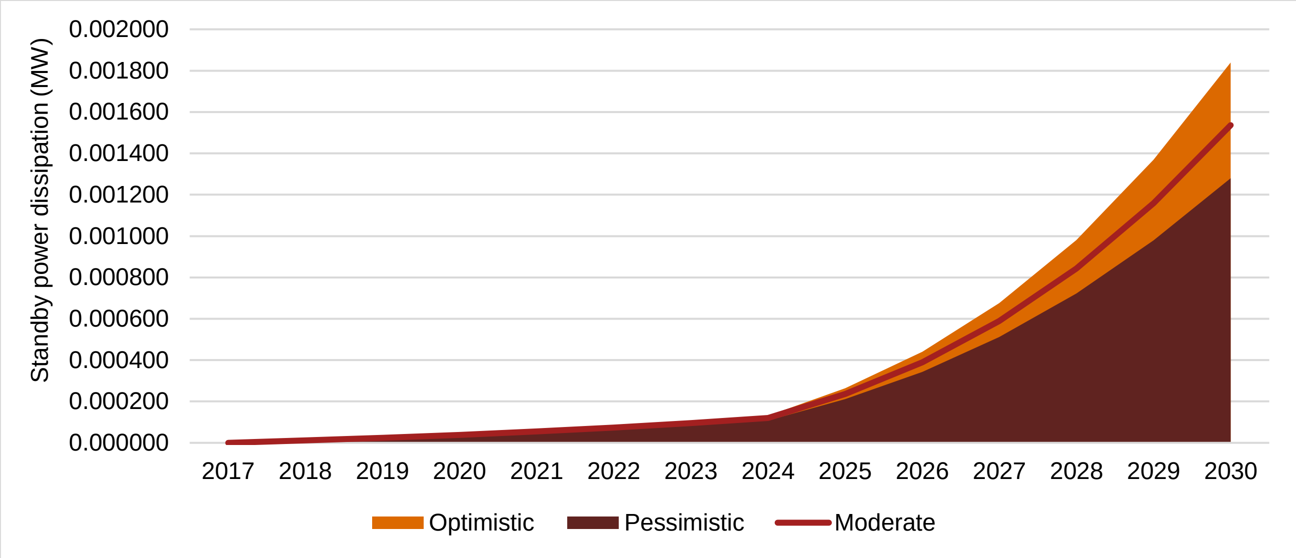
Wi-Fi has been identified as the only communication technology that is being used currently in the smart geyser space (refer Task I). Wi-Fi based smart geysers use Wi-Fi/IR remote technology and dissipate a net standby power of 0.001 W.

Table 51: Standby power forecast of smart geysers

Sr. no.	Smart geysers	Scenario	Net standby power (MW)	
			2017	2030
1	Wi-Fi based smart geyser	Optimistic (9%)	0.00	0.00183
		Moderate (7.5%)	0.00	0.00153
		Pessimistic (6%)	0.00	0.00128

As estimated in the table above, Wi-Fi based smart geysers in an optimum scenario dissipate a maximum amount of standby power, whereas the same in a pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 27: Standby power analysis



Hence, according to the above graph, the maximum standby power dissipation using Wi-Fi/IR is **0.0018 MW** and the minimum standby power dissipation using Wi-Fi/IR is **0.0013 MW**, as projected for 2030.

6.1.8. Smart refrigerators

As estimated in the Task III projection, the number of smart refrigerators are negligible but will grow to 140.17 million, 105.33 million and 78.65 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

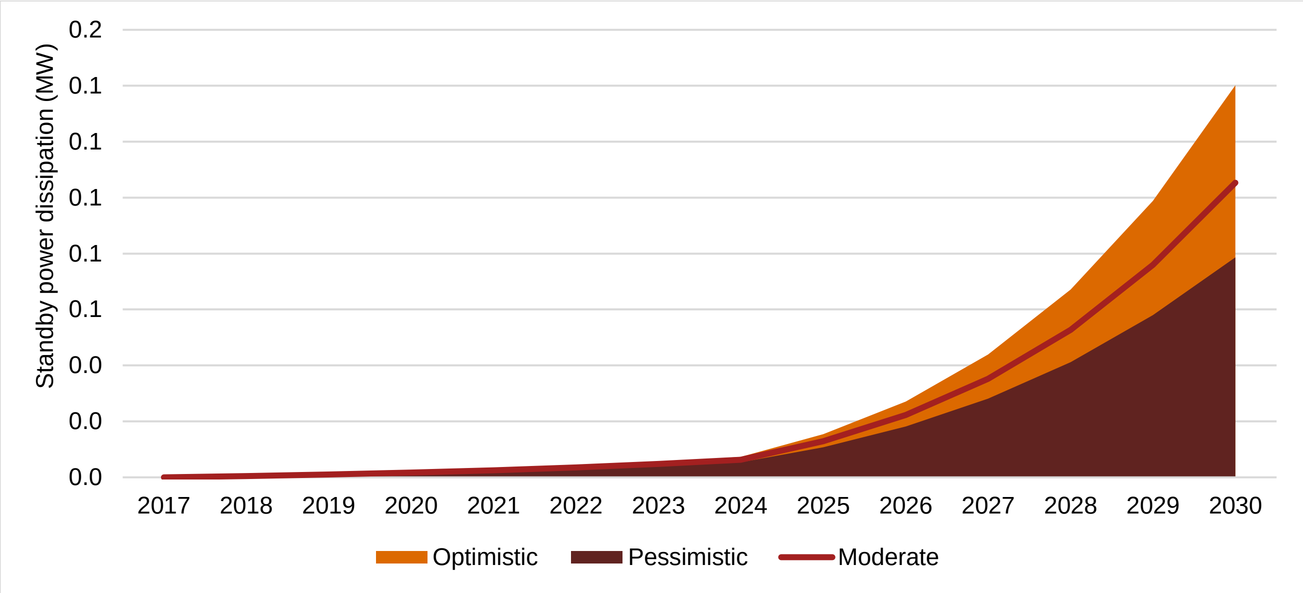
Only one communication technology has been identified that is being used currently in the smart refrigerator space (refer Task I). RF-based refrigerators dissipate a net standby power of 0.001 W.

Table 52: Standby power forecast of smart refrigerators

Sr. no.	Smart refrigerators	Scenario	Net standby power (MW)	
			2017	2030
1	RF-based refrigerator	Optimistic (15%)	0.00	0.140
		Moderate (13%)	0.00	0.105
		Pessimistic (10%)	0.00	0.078

As estimated in the table above, RF-based smart refrigerators in an optimum scenario dissipate the maximum amount of standby power, whereas the same in a pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 28: Standby power analysis



Hence, according to the above graph, the maximum standby power dissipation using RF technology is **0.140 MW** and the minimum standby power dissipation using the same technology is **0.078 MW**, as projected for 2030.

6.1.9. Smart TVs

As estimated in the Task III projection, the number of smart TVs will grow from 5.56 million to 375.94 million, 282.37 million and 229.09 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

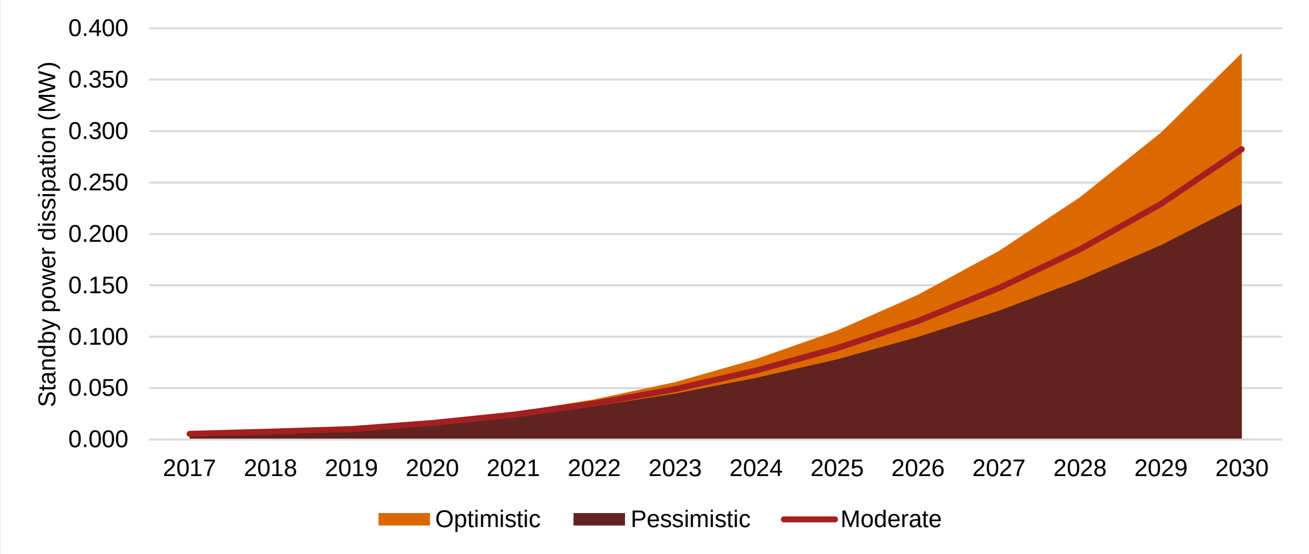
Currently, only one communication technology has been identified and is being used in the smart TV space (refer Task I). Wi-Fi based TVs dissipate a net standby power of 0.001 W.

Table 53: Standby power forecast of smart TVs

Sr. no.	Smart TVs	Scenario	Net standby power (MW)	
			2017	2030
1	Wi-Fi based TV	Optimistic (7%)	0.006	0.376
		Moderate (5%)	0.006	0.282
		Pessimistic (3%)	0.006	0.229

As estimated in the table above, Wi-Fi based TVs in the optimum scenario dissipate the maximum amount of standby power, whereas the same in the pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 29: Standby power analysis



Hence, according to the above graph, the maximum standby power dissipation using Wi-Fi is **0.376 MW** and the minimum standby power dissipation using the same technology is **0.229 MW**, as projected for 2030.

6.1.10. Home and building automation systems

As estimated in the Task III projection, the number of smart home hubs will grow from 0.15 million to 0.4 million, 0.27 million and 0.21 million, considering optimistic, moderate and pessimistic scenarios, in that order, by 2030.

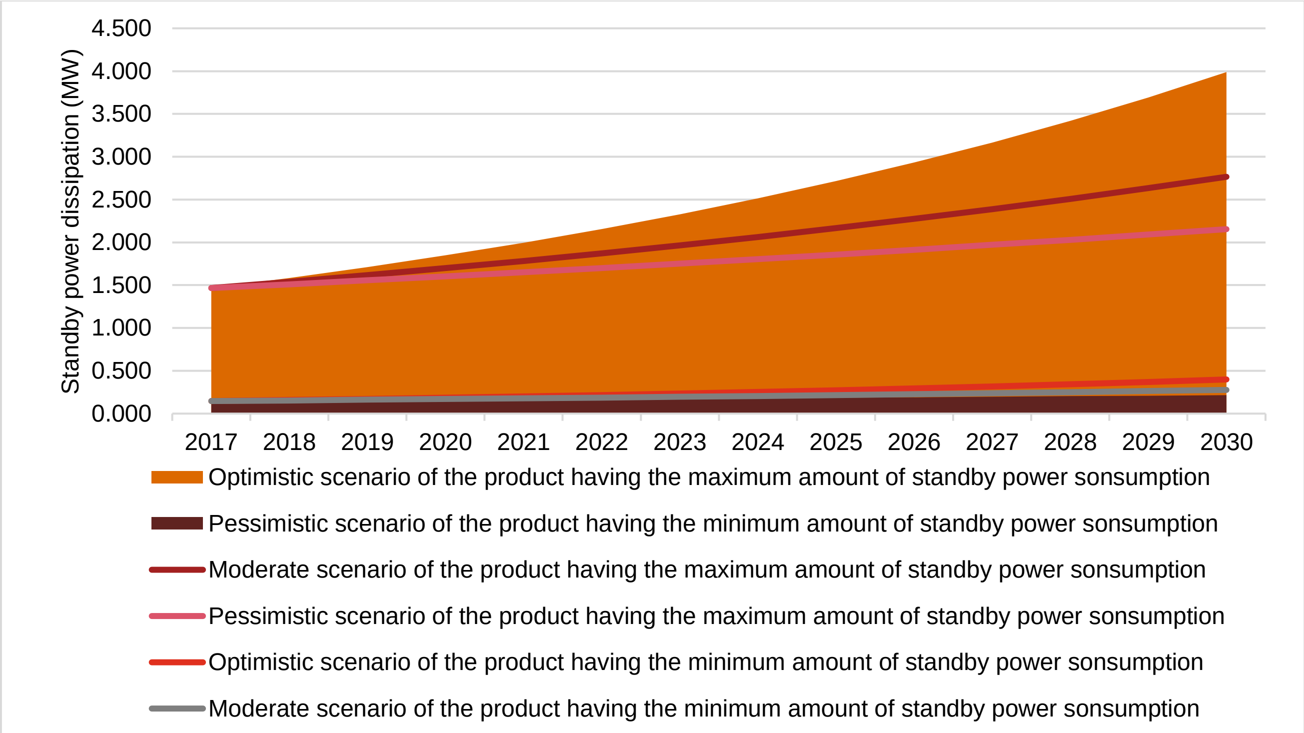
Currently, two communication technologies have been identified and are being used in the smart hub space (refer Task I). KNX-based home automation systems dissipate a net standby power of 1 W, whereas ZigBee/Wi-Fi/IP-based home automation systems dissipate 10 W of standby power.

Table 54: Standby power forecast of home and building automation systems

Sr. no.	Home and building automation systems	Scenario	Net standby power (MW)	
			2017	2030
1	KNX-based home automation system	Optimistic (8%)	0.147	0.399
		Moderate (5%)	0.147	0.277
		Pessimistic (3%)	0.147	0.215
2	ZigBee/Wi-Fi/IP-based home automation system	Optimistic (8%)	1.467	3.989
		Moderate (5%)	1.467	2.766
		Pessimistic (3%)	1.467	2.154

As estimated in the table above, ZigBee/Wi-Fi/IP-based home automation systems in an optimum scenario dissipate the maximum amount of standby power, whereas KNX-based home automation systems in a pessimistic scenario dissipate the minimum amount of standby power (as depicted in the graph below).

Figure 30: Standby power analysis



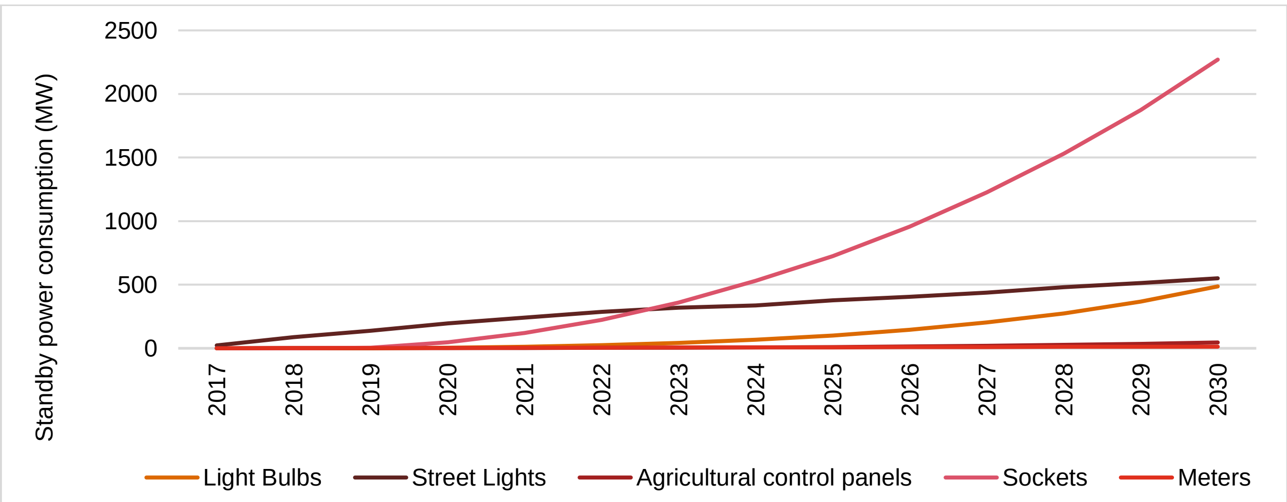
Hence, according to the above graph, the maximum savings in power dissipation because of using low-power communication technology—that is, KNX—is **3.774 MW**, as projected for 2030.

6.2. Energy efficiency potential by employing low-power communication technologies

There are two possible scenarios based on the employment of communication technologies by a particular IoT product as the net standby power depends upon the selection of technology.

Scenario A considers that the products covered employ communication technology with a maximum standby power, whereas scenario B considers that the products covered employ the communication technology with a minimum standby power, among the studied communication technologies.

Figure 31: Standby power projections under scenario A

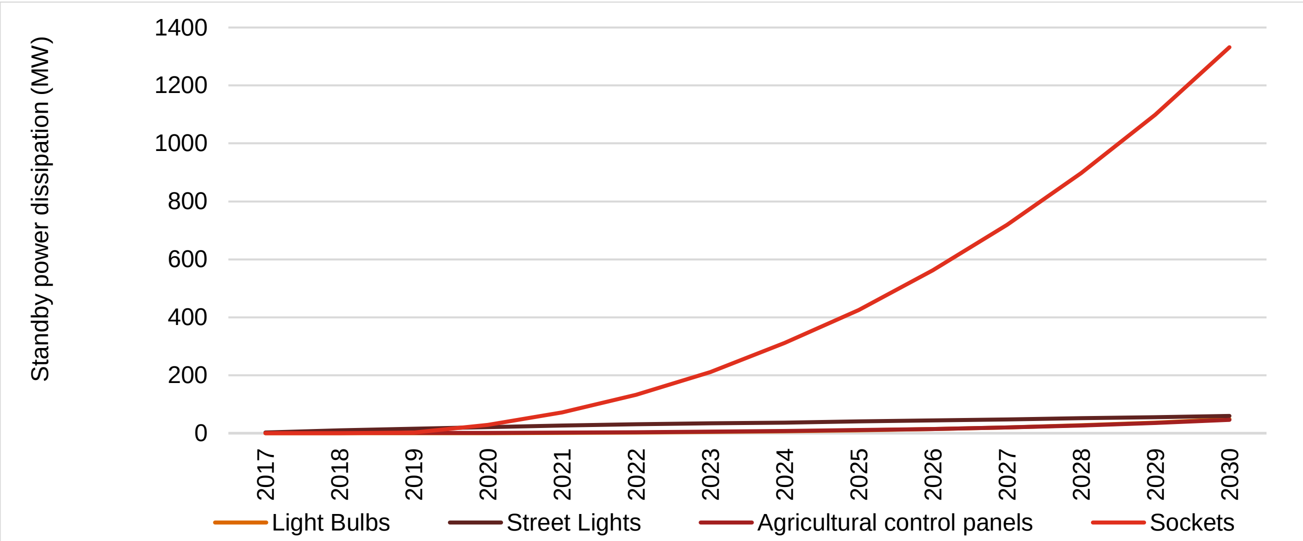


Scenario A

- The standby power dissipation of the IoT devices considered in the report is growing by 74.7% from 2017 till 2030 in this scenario.
- Of the IoT solutions studied in the report, the total standby power dissipation by 2030 comes out to be 3375.5 MW. Hence, the additional load increment due to standby power will be 3.37 GW, which forms 1% of the currently installed capacity of India.
- The total impact on the energy consumption comes out to be 27.15 TWh for FY 2029–2030 (assuming that all the proposed IoT solutions stay in operation for 24 hours a day, except street lights that remain on for 12 hours a day).
- The most significant contributors to standby power dissipation till 2030 in India are expected to be smart sockets, smart light bulbs and smart street lights.
- Smart sockets consume 2.27 GW, which form 67% of the total standby power dissipation.

Scenario B

Figure 32: Standby power projections under scenario B



- The network-related standby power dissipation of the IoT devices considered in the report is growing by 64.7% in this scenario.
- Of the IoT solutions studied in the report, the total standby power dissipation by 2030 comes out to be 1487.4 MW. **Hence, the additional load increment due to standby power will be 1.48 GW, which forms 0.45% of the currently installed capacity of India.**
- **The total impact on the energy consumption comes out to be 12.76 TWh for FY 2029–2030** (assuming all the proposed IoT solutions stay in operation for 24 hours a day, except street lights that remain on for 12 hours a day).
- The most significant contributors to the standby power dissipation till 2030 in India are expected to be smart light bulbs, smart meters and smart sockets, where smart sockets contribute around 90% to the total standby power dissipation.

6.3. Energy efficiency potential based on user behavioural patterns and device automation

This section estimates the energy efficiency potential of a smart product, depending upon user operation and device automation. Different scenarios have been covered under which a user can operate a smart device and estimate energy efficiency based on those scenarios using mathematical equations. Exact energy savings can only be estimated for a particular user as it will vary from user to user. Peak load reduction has also been estimated in scenarios where load shift is possible.

6.3.1. Smart bulbs

Smart light bulbs can be operated remotely through an app or via Bluetooth. Hence, it gives the user the choice to switch it on/off from a distance. A user can also adjust the brightness of the bulb according to the surrounding lighting situations. Hence, the operating pattern and the wattage reduction due to dimming will determine the saving potential. Energy will be saved in cases when the user dims the light or switches it off whenever the bulb is not in use. However, if a bulb a switched on remotely (either for safety reasons or other), then additional energy would be consumed.

The energy savings due to the use of smart bulbs can be estimated as:

Total energy savings = $\sum_{i=1}^{n} a_i \times N \times \left(H_{d(i)} \times W_{d(i)} + H_{off(i)} \times W_i - H_{on(i)} \times W_i\right)$

Where,

N = total number of smart light bulbs installed in the country

a_i = denotes a proportion of smart light bulbs operating with the same power dissipation and uses the same operating philosophy and $a_1 + a_2 + a_3 + \dots\dots\dots + a_n = 1$

H_d = the number of hours for which light bulbs are dimmed

H_{on} = the number of hours for which the bulbs are being switched on

H_{off} = the number of hours for which the light bulbs are being switched off

W_d = the wattage reduction due to the dimming of one light

W = wattage of one light bulb

6.3.2. Smart street lights

Smart street lights provide light operators with the opportunity to manually or automatically turn the lights on/off, according to their requirements. They can be operated via a manual timer or can be automatically controlled. Smart street lights can also be dimmed as and when the need arises. Hence, the operating pattern and the wattage reduction due to dimming will determine the saving potential.

A simple mathematical relation can be formulated based on the above parameters. It will depend on the different operating scenarios and the wattage of the street light.

To calculate the overall saving potential due to all the smart street lights, one has to assume that the total number of smart street lights installed in the country is, say N. $a_1, a_2, \dots\dots\dots\dots a_n$ are the probability of occurrence of different scenarios under which the smart street lights can be operated or the number of ways in which they can be dimmed up to a certain wattage, where $a_1 + a_2 + a_3 + \dots\dots\dots + a_n = 1$.

Hd is the number of hours for which street lights are dimmed and Hs is the number of hours for which the street lights are being switched off.

Wd is the wattage reduction due to the dimming of one light and W is the wattage of a street light. Therefore, combining these parameters, the following equation can be derived,

Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times \left(H_{d(i)} \times W_{d(i)} + H_{s(i)} \times W_i\right)$

6.3.3. Smart agricultural control panels

Smart control panels provide farmers/users an opportunity to manually or automatically turn the pumps on/off according to their requirements. They can be operated via a manual timer or can be automatically controlled.

A simple mathematical relation can be formulated based on the user behaviour pattern displayed. It will depend on the different operating scenarios (means of operation employed by the farmers) and the pump size.

To calculate the overall saving potential due to all the smart control panels, one has to assume that the total number of smart control panels installed in the country is, say N. a_1, a_2, ... a_n are probability of occurrence of different scenarios under which the smart control panels can be operated or different pump sizes installed, where $a_1 + a_2 + a_3 + \dots + a_n = 1$.

Hoff is the number of hours for which the pumps are being switched off as a result of better control and operation and W is the wattage of a pump. Therefore, combining these parameters, the following equation can be derived,

Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times (H_{off(i)} \times W_i)$

6.3.4. Smart sockets

Various home appliances and products can be controlled via smart sockets. Smart sockets can turn the appliances or devices connected to them on/off. They can be operated via a manual timer or can be automatically controlled (in case when smart socket senses that a device has been fully charged, it can simply cut off its supply automatically to protect overcharging of the battery).

A simple mathematical relation can be formulated based on the user behaviour pattern displayed. It will depend on the different types of appliances that a user connects with the sockets.

To calculate the overall saving potential due to all the smart sockets, one has to assume that total number of smart sockets installed in the country is, say N. a_1, a_2, ... a_n are probabilities of occurrence of different scenarios under which appliances are connected with the sockets, where $a_1 + a_2 + a_3 + \dots + a_n = 1$.

Hoff is the number of hours for which the devices are being switched off as a result of better control and operation via smart sockets, Wmanual is the wattage of a device which is being switched off via manual timer and Wauto is the wattage of a device which is being switched off via an automatic timer. Therefore, combining these parameters, the following equation can be derived,

Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times (H_{off(i)} \times W_{manual(i)} + H_{off(i)} \times W_{auto(i)})$

6.3.5. Smart meters

There are three components to this:

- Scenario where people understand their consumption via the data displayed on the smart meter (on a daily/monthly or quarterly basis) and reduce their energy consumption
- Auto demand response (DR) — utilities would involuntarily reduce the load of the consumers who are subscribed
- Manual DR — utilities offer an incentive to consumers to reduce their load

It is important to note that only loads which would lead to energy consumption reduction (temperature regulation of HVAC, lifts, escalators) and not shifting have been considered (process driven especially in case of industries). Therefore, energy reduction would be only majorly applicable to the domestic and commercial consumers. The reduction would be:

$$\sum_{i=1}^{n} a_i \times N \times W_{red_i} \times H_i + \left(\sum_{j=1}^{n} b_j \times W_{red_j} + \sum_{k=1}^{n} C_k \times W_{red_k}\right) \times H_{jk}$$

Where,

$a_1 + a_2 + \ldots\ldots\ldots\ldots\ldots + a_n = 1$ and ai denote probabilities of occurrence of various operating or load reduction patterns displayed by people

N = total number of consumers with smart meters

W_{red} = load reduction under various circumstances

H_i = hours for which load reduced by consumers

b_j = denotes various loads which the utility can reduce and is dependent on the incentive paid to the consumer

c_k = denotes the load which consumer can reduce and is dependent on the incentive paid to the consumer

H_{jk} = duration of a DR event

For peak demand reduction, the following formula can be used:

$$\sum_{i=1}^{n} a_i \times N \times W_{red_i} \times CIF_i + \left(\sum_{j=1}^{n} b_j \times W_{red_j} + \sum_{k=1}^{n} C_k \times W_{red_k}\right)$$

CIF_i = Peak coincidence factor of the load reduced by the consumer. Also, for peak load reduction all the loads would be considered including process driven.

Please note that CIF is not applied to DR events where the load will be reduced during the peak itself.

6.3.6. Smart ACs/thermostats

A smart AC can be switched on or off remotely and can better control room temperature via sensing its surroundings.

A simple mathematical relation can be formulated based on user behaviour patterns displayed. It will depend on the wattage reduced because of better temperature control, increase in operating wattage when the AC was turned on for some extra time remotely (turning the AC on even before reaching home to keep the room chill on arrival) and wattage reduction when the AC was switched off remotely.

To calculate the overall saving potential due to all the smart ACs, one has to assume that the total number of smart ACs installed in the country is, say N. $a_1, a_2, \ldots\ldots\ldots a_n$ are probabilities of occurrence of different scenarios under which the AC is being operated, where $a_1 + a_2 + a_3 + \ldots\ldots + a_n = 1$.

Hoff is the number of hours for which the AC is being switched off as a result of better control and operation remotely, Hon is the number of hours for which the AC is being switched on remotely and Hd is the number of hours for which the wattage reduced because of better surrounding sensing. Wd is the wattage reduced in case of surrounding sensing and W is the wattage of a smart AC. Therefore, combining these parameters, the following equation can be derived,

Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times \left(H_{d(i)} \times W_{d(i)} + H_{off(i)} \times W_{(i)} - H_{on(i)} \times W_i\right)$

6.3.7. Smart geysers

A smart geyser can be either switched on (either remotely via phone or automatically via timer) or off (either remotely via phone or automatically via a timer or temperature detection when the required temperature is attained).

There might be a possibility of peak load reduction as users can shift their geyser usage timings provided an incentive to be given for this shift (TOD electricity tariff structure).

A simple mathematical relation can be formulated based on the user behaviour patterns displayed for the estimation of energy savings. It will depend on the wattage reduced because of times when the geyser was switched off and the wattage increased because of times when the geyser was switched on.

To calculate the overall saving potential due to all the smart geysers, one has to assume that the total number of smart geysers installed in the country is, say N. a_1, a_2, ... a_n are probabilities of occurrence of different scenarios under which a geyser is being operated, where $a_1 + a_2 + a_3 + \dots + a_n = 1$.

H_{off} is the number of hours for which a geyser is being switched off and Hon is the number of hours for which a geyser is being switched on. W is the wattage of a smart geyser. Therefore, combining these parameters, the following equation can be derived,

Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times \left(H_{off(i)} \times W_{(i)} - H_{on(i)} \times W_i\right)$

For peak load demand reduction, the following formula can be used:

$$\sum_{i=1}^{n} \beta_i \times W_i \times CIF_i$$

Where,

β_i is the percentage of total smart geysers customer who would shift

CIF_i = Peak coincidence factor of the load reduced by the consumer

Please note that CIF is not applied to DR events where the load will be reduced during the peak itself.

6.3.8. Smart refrigerators

A smart refrigerator can automatically control the temperature via sensing the state of the products kept inside and outside climatic conditions.

A simple mathematical relation can be formulated based on automatic control. Energy savings will be dependent on the wattage reduced because of better temperature control.

To calculate the overall saving potential due to all the smart refrigerators, one has to assume that the total number of smart refrigerators being used in the country is, say N. a_1, a_2, ... a_n are probabilities of occurrence of different scenarios under which a refrigerator controls the temperature, where $a_1 + a_2 + a_3 + \dots + a_n = 1$.

H_d is the number of hours for which the wattage reduced because of better temperature control. W_d is the wattage reduced in the respective scenario. Therefore, combining these parameters, the following equation can be derived,

Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times \left(H_{d(i)} \times W_{d(i)}\right)$

6.3.9. Smart TVs

A smart TV can be switched off remotely when it is not in usage.

A simple mathematical relation can be formulated based on user behaviour patterns displayed. It will depend on the wattage reduction when the TV was switched off remotely.

To calculate the overall saving potential due to all the smart TVs, one has to assume that the total number of smart TVs installed in the country is, say N. a_1, a_2, ... a_n are probabilities of occurrence of different scenarios under which the TV is being switched off and its wattage, where $a_1 + a_2 + a_3 + \dots + a_n = 1$.

Hoff is the number of hours for which a TV is being switched off. W is the wattage of a smart TV. Therefore, combining these parameters, the following equation can be derived, Total energy savings = $\sum_{i=1}^{n} = a_i \times N \times (H_{off(i)} \times W_{(i)})$

6.3.10. Home and building automation systems

It basically consists of a platform from which different devices/home appliances can be connected and controlled. Some devices such as smart bulbs can be dimmed to a certain wattage according to the surroundings. Some can either be switched on/off remotely.

A simple mathematical relation can be formulated based on the user behaviour pattern. It will depend on the wattage reduced, increase in operating wattage when the devices are turned on remotely and wattage reduction when the devices are switched off remotely.

To calculate the overall saving potential due to all the home and building automation systems, one has to assume that the total number of such systems installed in the country is, say N. a_1, a_2, ... a_n are probabilities of occurrence of different scenarios under which such systems are being operated, where $a_1 + a_2 + a_3 + \dots\dots\dots + a_n = 1$. j_1, j_2... j_m is the number of devices connected to a single system in each scenario.

H_{off} is the number of hours for which devices are being switched off remotely, H_{on} is the number of hours for which devices are being switched on remotely and H_d is the number of hours for which the wattage reduced because of better control. W_d is the wattage reduced and W is the wattage of a single device connected to a single system in every scenario. Therefore, combining these parameters, the following equation can be derived,

Total energy savings =$\sum_{i=1}^{n} = a_i \times N \times [\sum_{j=1}^{m}(H_{off(j)} \times W_j - H_{on(j)} \times W_j + H_{d(j)} \times W_{d(j)})]$

7. Conclusion

This chapter includes the existing policy and regulatory framework for IoT devices in India, as well as the initiatives that took place in India to promote and encourage the usage of smart products. Standby power standards present for smart devices have been examined and finally some recommendations have been presented to limit the standby power dissipation and ways to expand the scope of building codes and rating systems to cover advanced IoT aspects.

7.1. IoT policy and regulatory framework in India

In October 2014, the Department of Electronics and Information Technology (DeitY) of the Ministry of Communications and IT released a draft IoT policy. The draft policy has the following set objectives:

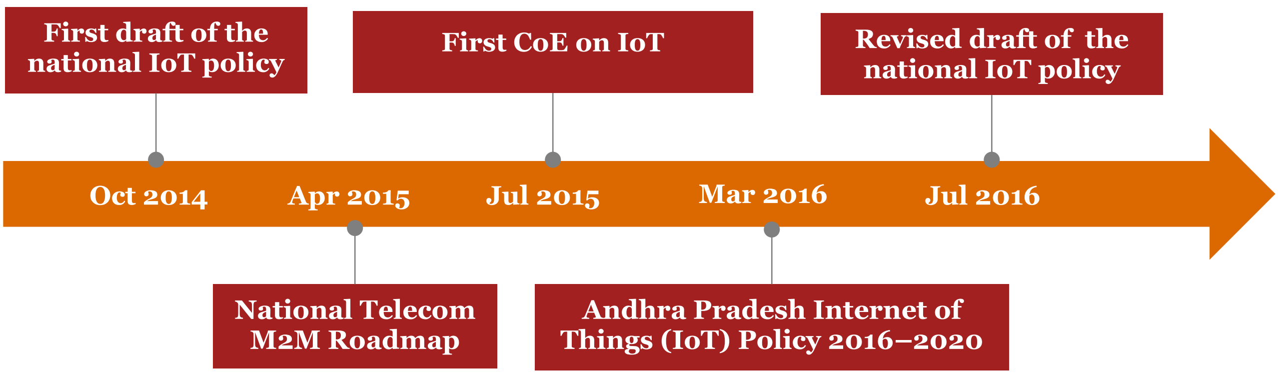
- To create an IoT industry worth 15 billion USD in India by 2020, with the number of connected devices increasing from around 200 million to over 2.7 billion by 2020, making the assumption that India would have a share of 5–6% of the global IoT industry.
- To develop capacity on both the human and technological fronts for IoT-specific skill sets, aimed at both domestic and international markets.
- To enable research and development of assisting technologies.
- To develop IoT products specific to Indian needs in multiple domains.

In April 2015, the 'National Telecom M2M Roadmap' was released by the Union Minister of Communication and Information Technology. The Department of Telecommunications (DoT) has come up with this roadmap which will serve as a single reference document for all M2M stakeholders in India. India's first Centre of Excellence (CoE) on IoT was launched on 1 July 2015 in Bengaluru, Karnataka. The CoE is jointly set up by the National Association of Software and Service Company (NASSCOM), Department of Electronics and Information Technology (DeiTy) and Education and Research Network (ERNET). The IoT centre, which allows start-ups to build a prototype and test them, will focus on building solutions for applications such as agriculture, automobile, telecom, healthcare and consumer goods.

In March 2016, Andhra Pradesh launched a one of its kind state policy on IoT, 'Andhra Pradesh Internet of Things (IoT) Policy 2016–2020', with a vision to establish the state as an IoT hub by 2020—the perfect destination for IoT entities/units. The policy was also released to help augment the state gross domestic product and help with the generation of additional gainful employment opportunities to the educated youth of the state in the IoT space. In July 2016, a revised draft of the national IoT policy was released.

A snapshot has been attached below which lists the above initiatives regarding IoT and smart devices in chronological order.

Figure 33: Timeline of IoT initiatives in India



The Telecommunication Engineering Center (TECI), the technical arm of the DoT, has started working on India-specific IoT standards, in line with evolving global standards.

7.2. Standby power standards in India

To examine the existing standby power standards, it is important to first understand the components of power consumed in a smart device. A smart electrical device generally amounts to two types of power: the power drawn when a device operates in active mode and when a device operates in idle mode—that is, standby mode. Usually, device power is the major source of power consumption for any smart device, whereas standby power forms a miniscule percentage of the device power. Hence, standby power can't be a part of a standards and labelling programme as the quantitative difference between standby powers of devices would be negligible. However, standby power can be a part of the eligibility criteria considered for standards and labelling.

India currently doesn't have properly established and thorough IoT standards that can be applicable for all the smart devices and appliances available today. However, we have come a long way since the inception of IoT.

Some standards have been developed in specifying standby power consumption. One such internationally recognised standard used for standby power consumption in India is International Electro Technical Commission (IEC) 62301: 2011. Its second edition was released in 2011. The IEC 62301 test applies to all devices plugged into the electric mains by the end user. It is designed to measure the energy consumption of devices while in standby and other low-power modes. Currently, the Bureau of Energy Efficiency (BEE) uses IEC 62301: 2011 in their standards and labelling (S&L) specifications for colour TVs. It is expected that India will soon come out with similar standards for other appliances and devices as the different IoT elements (gateways, actuators, sensors, etc.) become mainstream.

7.3. Recommendations

Taking cue from a few global initiatives by other countries to reduce standby power, India can also implement such practices to encourage the use of low-power communication technologies and limit the standby power consumption from a device. This section attempts to suggest possible methods to restrict standby power either by using a suitable communication technology or by initiating a policy which puts a cap on its upper limit. Lastly, the building automation sector has been studied separately as it makes use of a large number of smart devices simultaneously which notably increases the standby power. Some green building codes and rating systems prevalent in India have been explored and a few additional inclusions are proposed to better incorporate the concept of standby power in such systems.

7.3.1. Restricting standby power – One Watt initiative

Many products covered in the report have their standby power lying somewhere in the ranges greater than 1 W. Many countries have introduced standards which limit standby power. India can also launch such initiatives by keeping the threshold standby power to 1 W for all electronic and electrical devices.

The table below illustrates the standby-power dissipation impact and net savings in power consumption from the products (having standby power greater than 1 W) if the 1 W initiative becomes a reality. If such standards come into effect, the **connected grid load can be lowered by 3 GW, which forms around 0.9% of the current installed capacity in India.**

Note: Certain factors and market drivers have been considered to assume the penetration rates of smart devices from 2017 till 2030.

Table 55: Net power savings analysis

IoT solution	Product covered	Current standby power (W)	Respective standby dissipation (in 2030) (MW)	New standby power (W)	Respective Standby dissipation (in 2030) (MW)	Power savings (MW)
Smart street lights	GSM/GPRS-based group controller	5.0	460	1.0	92	**368**
	GSM/GPRS-based individual lamp controller	6.0	550	1.0	92	**458**
Smart agricultural panels	GSM-based mobile starters	1.5	46	1.0	31	**15**
Smart sockets	Wi-Fi based smart socket	3.0	2,270	1.0	757	**1,513**
	GSM-based smart plug + app	1.76	1,332	1.0	757	**575**
Home and building automation	ZigBee/Wi-Fi home automation system	10.0	2.76	1.0	0.277	**2.5**
Net power savings						**2,931**

According to the table, power savings after the 1 Watt initiative will be highest in smart sockets—that is, 71% of the net power savings, whereas the savings from home and building automation systems will form a mere 0.08% of the net power savings.

The BEE can consider restricting the standby power of all the electrical devices to 1 W and can make this the eligibility criteria under their standards and labelling programme so that devices having a standby power greater than 1 Watt would not be labelled.

7.3.2. Low-power communication technology

As it is evident from the report, standby power of RF-powered devices such as refrigerators and meters is significantly lower (i.e. 0.001 and 0.025 W respectively) when compared with the devices using GSM or Wi-Fi.

However, there are some challenges associated with these low-powered technologies. They need a gateway to connect to the Internet (therefore, one has to factor in the standby power of a gateway, if any) and can carry only small amounts of data. Hence, the usage of such low-powered technologies is application-specific. They can be very useful where a large number of devices need to be connected continuously but the amount of data to be transferred is small. Low-powered technologies can be very useful in street lighting and the meter space as both these applications require very low power to send/receive data.

To encourage the use of low-power communication technologies in appropriate applications, the Government of India can consider making amendments to the Indian Wireless Telegraphy Act, 1933. The DoT can list 'promoting low-power communication technologies' as an objective of the 'India Wireless Telegraphy Act, 1933', and can withdraw licence requirements to possess any low-power wireless telegraphy apparatus operating in the frequency band of 865–867 MHz.

7.3.3. Building codes and rating systems

The impact of the building industry on the environmental is significant. Buildings annually consume more than 20% of the electricity used in India. Building management systems consisting of smart IoT components and devices can be an integral part of a building as these systems can optimise and minimise overall power dissipation. There are various green building codes and rating systems being followed internationally.

India has in place the Energy Conservation Building Code (ECBC) and green building rating systems such as Leadership in Energy & Environmental Design (LEED), India, Indian Green Building Council (IGBC) and Green Rating for Integrated Habitat Assessment (GRIHA) India. The table below attempts to explain several codes and rating systems followed in India, how these codes incorporate the idea of IoT devices and up to what extent. Then some additional inclusions have been proposed to make the existing codes more comprehensive, covering some advanced concepts of smart and connected devices.

Table 56: Proposed inclusions in existing green building codes and rating systems

Sr.no	Code/ rating system	Introduction	What it includes	Proposed inclusion
1.	**ECBC**	• The purpose of the ECBC is to provide minimum requirements for the design and construction of energy-efficient buildings. • The code also provides two additional sets of incremental requirements—that is, ECBC+ SuperECBC—for buildings to achieve enhanced levels of efficiency that go beyond the minimum requirements. • The code is applicable to buildings or building complexes that have a connected load of 100 kW or greater or a contract demand of 120 kVA or greater and are intended to be used for new commercial buildings.	• It includes smart devices in its rudimentary form and uses the word 'controls' for reference (although controls don't always mean 'smart' devices in the code). • These are basic sensors that can sense the surroundings and can pass on the collected information in the form of signals to a gateway, actuator or a server.	• Smart devices and components that can perform complex actions such as controlling the temperature of an AC after the user/operator sends the command via its mobile to the AC's sensing system. • As of now, these controls have been suggested for ECBC+ and SuperECBC buildings. • Such smart controls can be made a part of the ECBC itself under the prescriptive requirements in order to optimise and conserve additional power in a building.
2.	**LEED India**	• It is a globally recognised symbol of excellence in the green building sector. • LEED certification ensures electricity cost savings and lower carbon emissions. • LEED prerequisites are preliminary requirements to get a	• As part of LEED 2011, for new construction and major renovations, heating, ventilating, air conditioning and refrigeration (HVAC&R), humidity, glare and energy systems automation controls have been talked about.	• Under LEED credits, LEED can add another credit to a project/building having a comprehensive Energy Management Information System (EMIS), which can measure, control and optimise the power distribution of the appliances/devices

Sr.no	Code/ rating system	Introduction	What it includes	Proposed inclusion
		building LEED certified. • After the basic certification, one can further opt for LEED credits within their chosen rating system.	• It also considers installing diagnostics within the control system to alert the user/operator when equipment is not being optimally operated.	connected and installed throughout the building. • After achieving this credit, buildings can earn LEED points and other awards.
3.	**IGBC**	• The IGBC offers a wide array of services, which include developing new green building rating programmes, certification services and green building training programmes. • The IGBC has its own rating system, covering all types of buildings. However, to keep our study simple and due to its limited scope, only new buildings and green home rating systems have been considered.	• The IGBC new building and green home rating systems include daylight sensors and occupancy/motion sensors under the prescriptive approach and the building management system (BMS) under mandatory energy efficiency requirements. • It also includes fresh air monitoring systems and CO_2 control and monitoring systems under BMS of renewable energy credits.	• The BMS can be extended to the building automation system (BAS), which can include detailed ventilation, lighting, power systems, fire systems and security systems as a credit requirement. • In addition to controlling the building's internal environment, BAS can be linked to access control or other security systems such as closed-circuit television (CCTV) and motion detectors as their power dissipation is quite high.
4.	**GRIHA**	• It is an indigenous rating system for green buildings in India, developed by the Energy and Resources Institute (TERI) • It functions as a tool to facilitate the design, construction and operation of green buildings that measure the ‘greenness’ of buildings in India. • Similar to the IGBC’s rating tool, it is a star-rating system that corresponds to a building’s performance as a green building.	• Talks about optimising the building performance and energy utilisation. • Majorly includes high efficiency mechanical systems.	• Inclusion of basic requirements and criterion of automated electrical devices and systems under optional clauses. • It can include an energy management system (EMS) that can keep track on the power usage of individual devices, as well as the entire building’s performance to optimise the power dissipation.

Annexure 1: Detailed product profiles

Smart light bulbs

Wi-Fi and ZigBee-compatible light bulb, along with colour ambiance starter kit

Table 57: Detailed product profile

Item	Description
Basic function	• General interior space illumination
Potential end users of the product	• Home owners, businesses
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Smart LED light bulbs and a bridge (gateway); a single bridge accommodates 50 connected smart bulbs.
Features and functionalities	• Remote control, light schedules, dimming, and colour adjustment via a smartphone • Varied lumen output at different colour temperatures – 800 lumens max@ 4,000k • Luminous efficacy increases with colour temperature and the maximum claimed efficacy – 80 lumens/W max@ 4,000k • Provides functional white light and all other shades of white from warm to cold colour temperatures • The app enables users to operate smart light bulbs on other home automation platforms – Apple Home Kit, Amazon Alexa, Google Home, NEST, etc.
Energy management features and functionalities	• Remote turn on/off and dimming
Communication technology/ies	• Wi-Fi and ZigBee
Communication architecture	• The bridge adopts ZigBee light link protocol 1.0 for communication with smart light bulbs; the ZigBee frequency band is 2,400–2,483.5 MHz; the bridge comes with an ethernet cable for communicating with the user through the Internet.
Wattage of the main object/equipment used for basic function	• 10 W
Rated and standby power of connected bridge	• Rated power – 1.5 W (rated max) • Standby power (per bulb) – 0.4 W (standby max)
Number of duty cycles required for specific IoT applications	• NA

Wi-Fi compatible smart light bulb

Table 58: Detailed product profile

Item	Description
Basic function	• General interior space illumination
Potential end users of the product	• Home owners, businesses
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Smart LED light bulbs (no gateway or hub required)
Features and functionalities	• Night vision, remote control, dimming and colour adjustment via smartphones; varied lumen outputs at different colour temperatures – 1,100 lumens at max colour temperature; provides functional white light and all other shades of white from warm to cold colour temperatures; the app works on iOS, Android and Windows 10; enables users to operate smart light bulbs on other home automation platforms – Amazon Alexa, Google Home, NEST etc.
Energy management features and functionalities	• Remote turn on/off and dimming
Communication technology/ies	• Wi-Fi
Communication architecture	• Smart bulb is synced through Wi-Fi on the user's smartphone app
Wattage of the main object/equipment used for basic function	• 11 W
Rated and standby power of IoT elements	• Standby power - 0.5 W
No. of duty cycles required for specific IoT applications	• NA

Bluetooth compatible smart light bulb

Table 59: Detailed product profile

Item	Description
Basic function	• General interior space illumination
Potential end users of the product	• Home owners, businesses
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Smart LED light bulbs (no gateway or hub required)
Features and functionalities	• Remote control and dimming via smartphone (only from inside home); 800 lumens at 2,700k. The smartphone app works on iOS and Android.

Item	Description
Energy management features and functionalities	• Remote turn on/off and dimming
Communication technology/ies	• Bluetooth
Communication architecture	• Smart bulb is synced through Bluetooth on the user's smartphone app
Wattage of the main object/equipment used for basic function	• 11 W
Rated and standby power of IoT elements	• 1 W (maximum standby power)
No. of duty cycles required for specific IoT applications	• NA

Smart street lights

GSM/GPRS-based group controller

Table 60: Detailed product profile

Item	Description
Basic function	• Adaptive dimming and remote controlling
Potential end users of the product	• Smart Cities, smart campuses, smart highways
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• **Remote terminal unit** (RTU) is responsible for communicating with the central server. It is a closed and secured unit with IP-65 rating**.** It has a manual and an auto switch and can hence can be operated accordingly. One feeder panel can control around 80–100 electric poles. It majorly consists of**:** • Contactor/relay • Miniature circuit breaker (MCB) • Surge protection device (SPD • SIM card • SD card • GPS system • GPU clock • Data logging system
Features and functionalities	• The controller supports five lamp control modes. Control can be based on user configurable on/off/dimming schedules programmed on a daily/monthly/yearly/special events basis such as holidays, warehouse inventory and stocking events. • It is a future-ready product as it is compatible to interface motion/occupancy sensors to enable

Item	Description
	motion-based dimming and ambient light sensors for daylight harvesting.
Energy management features and functionalities	• Remote turn on/off and dimming
Communication technology/ies	• GSM and GPRS
Communication architecture	• User/controller communicates with RTU through GSM technology and the RTU communicates with the central server through GPRS technology.
Wattage of the main object/equipment used for basic function	• Electric lamp – 20 W
Rated and standby power of IoT elements	• RTU – 5 W (standby power max)
Number of duty cycles required for specific IoT applications	• For RTU – 0.11% (as it transfers the data for 1 second every 15 minutes)

GSM/GPRS-based individual lamp controller

Table 61: Detailed product profile

Item	Description
Basic function	• Adaptive dimming and remote controlling
Potential end users of the product	• Smart Cities, smart campuses, smart highways
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• **1. Individual lamp controller (or RTU)** It is installed on every electric pole**.** It is a closed and secured unit with an IP-65 rating. It majorly consists of: • Contactor/relay • MCB • SPD • RF chip • GPS system • GPU clock • **Gateway** In this case, it has an SD card, SIM card and data logging system. One gateway can accommodate around 250 individual lamp controllers.
Features and functionalities	• The controller supports five lamp control modes. Control can be based on user configurable on/off/dimming schedules programmed on a daily/monthly/yearly/special event basis such as holidays, warehouse inventory and stocking events. • It is a future-ready product as it is compatible to interface motion/occupancy sensors to enable

Item	Description
	motion-based dimming and ambient light sensors for daylight harvesting.
Energy management features and functionalities	• Remote turn on/off and dimming
Communication technology/ies	• RF mesh and GSM/GPRS
Communication architecture	• RTUs communicate with the gateway through RF technology and the gateway communicates with the central server through GPRS technology.
Wattage of the main object/equipment used for basic function	• Electric pole – 20 W
Rated and standby power of IoT elements	• RTU – 1 W (standby max) Gateway – 5 W (standby max)
Number of duty cycles required for specific IoT applications	• For gateway – 0.11% (as it transfers the data for 1 second every 15 minutes)

Smart agricultural control panels

GSM-based mobile starters

Table 62: Detailed product profile

Item	Description
Basic function	• To temporarily reduce the load and torque in the power train and electric current surge of the motor during start-up.
Potential end users of the product	• Agricultural sector
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Starter panel attached with a mobile
Features and functionalities	• Over load protection • Can protect against voltage fluctuations • Has resistance temperature detectors that act as temperature sensors
Energy management features and functionalities	• Remote on/off through mobile, sleep mode operation
Communication technology/ies	• Quad band GSM
Communication architecture	• Mobile present in the remote location sends the enable/disable instruction message to the mobile connected with the starter panel.
Wattage of the main object/equipment used for basic function	• Starter panel – 10 W

Item	Description
Rated and standby power of IoT elements	• Rated power – 10 W • Standby power – 1.5 W
Number of duty cycles required for specific IoT applications	• NA

Smart sockets

Wi-Fi based smart socket

Table 63: Detailed product profile

Item	Description
Basic function	• Switching devices on/off
Potential end users of the product	• Residential sector
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Single-chip programmable microcontroller with built-in Wi-Fi connectivity
Features and functionalities	• Doesn't need a gateway. • Employs TCP transmission mode with around 13 mbps of data transfer rates. • Monitors power dissipated by other connected devices. • It can also schedule an action.
Energy management features and functionalities	• Energy monitoring
Communication technology/ies	• Wi-Fi
Communication architecture	• Cloud-enabled
Wattage of the main object/equipment used for basic function	• Socket – 3 W
Rated and standby power of IoT elements	• Standby power – 3 W (total power is equivalent to standby power as it always remains idle)
Number of duty cycles required for specific IoT applications	• NA

GSM-based smart plug + app

Table 64: Detailed product profile

Item	Description
Basic function	• Switching devices connected to it on/off.
Potential end users of the product	• Residential sector

Item	Description
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Smart plug
Features and functionalities	• Monitor energy consumption • Turn appliance on/off • Set scheduler • Get intruder alerts • Manage users • Control any appliance • Receive notifications
Energy management features and functionalities	• Energy monitoring
Communication technology/ies	• GSM
Communication architecture	• Cloud-enabled
Wattage of the main object/equipment used for basic function	• 1.76 W
Rated and standby power of IoT elements	• Standby power – 1.76 W
Number of duty cycles required for specific IoT applications	• NA

Smart meters

Wi-Fi based meter

Table 65: Detailed product profile

Item	Description
Basic function	• Metering, built-in analytics
Potential end users of the product	• Residential and business sector
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Meter • Wi-Fi router
Features and functionalities	• Peak load management • 10 mbps data transfer rate • Typical range – 30 m
Energy management features and functionalities	• Power management
Communication technology/ies	• Wi-Fi

Item	Description
Communication architecture	• Meter communicates with router using Wi-Fi and router communicates with the end server with Wi-Fi technology as well
Wattage of the main object/equipment used for basic function	• Meter – 0.9 W
Rated and standby power of IoT elements	• Max standby power (router) – 0.45 mille W
Number of duty cycles required for specific IoT applications	• NA

LoRa-based meter

Table 66: Detailed product profile

Item	Description
Basic function	• Metering, built-in analytics
Potential end users of the product	• Residential and business sector
Physical configuration - main object/equipment used for basic function and individual elements of the IoT solution	• Meter • Gateway
Features and functionalities	• Peak load management • 9,600 kbps data transfer rate • Typical range – 3 km
Energy management features and functionalities	• Power management
Communication technology/ies	• LoRa
Communication architecture	• Meter communicates with router using Wi-Fi and router communicates with the end server using Wi-Fi technology as well
Wattage of the main object/equipment used for basic function	• Meter – 0.128 W
Rated and standby power of IoT elements	• Standby power (gateway) – 9.24 mille W
Number of duty cycles required for specific IoT applications	• NA

RF-based meter

Table 67: Detailed product profile

Item	Description
Basic function	• Metering, built-in analytics

Item	Description
Potential end users of the product	• Residential and business sector
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Meter with RF chipset • No gateway required
Features and functionalities	• Peak load management • 19,200 bps data transfer rate • Typical range – 500 m
Energy management features and functionalities	• Power management
Communication technology/ies	• RF
Communication architecture	• Meter communicates with server using RF technology
Wattage of the main object/equipment used for basic function	• Meter – 1.6 W
Rated and standby power of IoT elements	• Standby power – 0.025 W
Number of duty cycles required for specific IoT applications	• NA

Smart ACs

Wi-Fi based AC

Table 68: Detailed product profile

Item	Description
Basic function	• Switching devices on/off. It can also schedule an action.
Potential end users of the product	• Residential sector
Physical configuration - main object/equipment used for basic function and individual elements of the IoT solution	• Smart AC and Wi-Fi module
Features and functionalities	• Doesn't need a gateway. • Employs 1 mbps data transfer rates, having a line of sight of 20 m.
Energy management features and functionalities	• Scheduling and energy monitoring
Communication technology/ies	• Wi-Fi, RF
Communication architecture	• Cloud-enabled

Item	Description
Wattage of the main object/equipment used for basic function	• Wattage of AC – 1,440 Watt
Rated and standby power of AC	• Standby power of IoT element – 0.1 W
No. of duty cycles required for specific IoT applications	• NA

Wi-Fi based AC + app

Table 69: Detailed product profile

Item	Description
Basic function	• Switching devices on/off. It can also schedule an action.
Potential end users of the product	• Residential sector
Physical configuration - main object/equipment used for basic function and individual elements of the IoT solution	• Smart AC and Wi-Fi module
Features and functionalities	• Turns appliances on/off. • Sets scheduler. • Employs 600 mbps data transfer rates and can be operated from anywhere with network connectivity.
Energy management features and functionalities	• Scheduling
Communication technology/ies	• Cloud communication
Communication architecture	• Cloud-enabled
Wattage of the main object/equipment used for basic function	• Wattage of AC – 1,560 W
Rated and standby power of AC	• Rated power of IoT element – 0.3–0.4 W • Standby power of IoT element – 0.001 W
Number of duty cycles required for specific IoT applications	• NA

Smart geysers

Wi-Fi based smart geyser

Table 70: Detailed product profile

Item	Description
Basic function	• Switching devices on/off. It can also schedule an action.
Potential end users of the product	• Residential sector
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Smart geyser and Wi-Fi module
Features and functionalities	• Energy consumption notification • Automatic failure notification to customers • Automatic dry heating detection • Works with a latency of 2 mille s
Energy management features and functionalities	• Energy consumption notification
Communication technology/ies	• Wi-Fi, IR remote technology
Communication architecture	• Cloud-enabled
Wattage of the main object/equipment used for basic function	• 2000 Watt
Rated and standby power of Gateway	• Rated power – 0.4 W • Standby power – 0.001 W
Number of duty cycles required for specific IoT applications	• NA

Smart refrigerators

RF-based smart refrigerator

Table 71: Detailed product profile

Item	Description
Basic function	• Cooling of eatables
Potential end users of the product	• Residential sector
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• Radio frequency identification (RFID) with SMA connector

Item	Description
Features and functionalities	• Reads RFID tags and informs the control centre and consumer about the expiry of items. • Has a display over the door.
Energy management features and functionalities	• NA
Communication technology/ies	• RF frequency
Communication architecture	• Cloud-enabled
Wattage of the main object/equipment used for basic function	• 2,000 W
Rated and standby power of Gateway	• Rated power – 0.5 W • Standby power – 0.001 W
Number of duty cycles required for specific IoT applications	• NA

Smart TVs

Wi-Fi based smart TV

Table 72: Detailed product profile

Item	Description
Basic function	• Wi-Fi enabled television
Potential end users of the product	• Residential and commercial users
Physical configuration – main object/equipment used for basic function and individual elements of the IoT solution	• It has a built-in Wi-Fi
Features and functionalities	• Clear voice III – enhances sound quality • Smart energy saving feature by limiting power. The feature includes backlight control for adjusting brightness. • Flexi-mount bracket
Energy management features and functionalities	• Smart energy saving by screen off function, brightness control
Communication technology/ies	• Wi-Fi
Communication architecture	• Local communication
Wattage of the main object/equipment used for basic function	• 70 W
Rated and standby power of IoT element	• Rated power – 0.3 W • Standby power – 0.001 W

Item	Description
No. of duty cycles required for specific IoT applications	• NA

Home and building automation

KNX-based home automation system

Table 73: Detailed product profile

Item	Description
Basic function	• Complete home automation
Potential end users of the product	• Residential and commercial sector
Physical configuration - main object/equipment used for basic function and individual elements of the IoT solution	• Total products covered in home automation (like light bulbs, curtains, smart appliances, sensors etc.) and gateway
Features and functionalities	• Energy consumption monitor • Automatic failure notification to customers • Control of connecting devices/appliances
Energy management features and functionalities	• Energy consumption notification
Communication technology/ies	• KNX
Communication architecture	• Wired technology with gateway
Wattage of the main object/equipment used for basic function	• NA
Rated and standby power of Gateway	• Rated power – 10 W • Standby power – 1 W
Number of duty cycles required for specific IoT applications	• NA

ZigBee/Wi-Fi home automation system

Table 74: Detailed product profile

Item	Description
Basic function	• Gateway integrating lighting controls/motorised curtain control integrated on app on handheld devices through Wi-Fi and IP
Potential end users of the product	• Residential and commercial sector

Item	Description
Physical configuration - main object/equipment used for basic function and individual elements of the IoT solution	• Ethernet-based connectivity to Wi-Fi router/modem
Features and functionalities	• Energy consumption notification • Interoperability with following platforms Modbus/BacNET Connectivity with BMS • Motion-based and time-scheduling based solutions for energy conservation
Energy management features and functionalities	• Motion-based and time-scheduling based solutions
Communication technology/ies	• ZigBee/Wi-Fi/IP
Communication architecture	• Cloud-enabled
Wattage of the main object/equipment used for basic function	• NA
Rated and standby power of modem/gateway	• Rated power – 10 W • Standby power – 10 W
Number of duty cycles required for specific IoT applications	• NA

PK/Jan 2018-11599