POLITECNICO DI MILANO

School of Industrial and Information Engineering

Master of Science in Management Engineering

SMART HOME ENERGY MANAGEMENT SYSTEM: STATE OF THE ART

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TABLE OF CONTENTS

LIST OF FIGURES:

ABSTRACT:

In the recent decades, there is a very rapid developments in technologies giving rise to various smart appliances entering the home and providing various benefits to the residents worldwide. This trend is accelerated by Internet of Things and various interconnected devices. These evolving smart appliances provides completely different value to the house residents. Changing the day to day activities of human lives into smarter, efficient, possibility to improve the qualities of the basic activities at home by automating routine activities, remote controlling and monitoring of all the interlinked devices of the house. This leads to the SMART HOME ENERGY MANAGEMENT. Safety, efficiency and control are the key drivers of these products.

Smart Home Energy Management systems not only provide the users with control and monitoring of energy usage, but it also provides insights about the usage, historical data, trend, possible chances to reduce the waste and ultimately the possibility to save energy and spend energy efficiently. This has been enabled by various technological developments. The various technologies used, spread of smart home energy management system across the world and its diffusion are examined in this report. From the analysis of existing data, the current rate of diffusion of Smart Home Energy Management System has been discussed and the potential future trends are briefly explained. Current rate of diffusion takes into the existing market condition, geographical areas, sales channel, technologies company types are discussed in detailed. In order to have a broader picture, worldwide Smart Home Energy Management System market has been taken into consideration.

Keywords: Smart Home, Energy Management Systems, IoT.

ABSTRACT (Italiano):

Negli ultimi decenni, c'è stato uno sviluppo molto rapido nelle tecnologie che ha dato origine a vari elettrodomestici intelligenti che entrano in casa e offrono vari vantaggi ai residenti in tutto il mondo. Questa tendenza è accelerata da Internet of Things e vari dispositivi interconnessi. Questi elettrodomestici intelligenti in evoluzione forniscono un valore completamente diverso ai residenti della casa. Trasformare le attività quotidiane della vita umana in una possibilità più intelligente ed efficiente di migliorare le qualità delle attività di base a casa automatizzando le attività di routine, il controllo remoto e il monitoraggio di tutti i dispositivi interconnessi della casa. Questo porta alla SMART HOME ENERGY MANAGEMENT. Sicurezza, efficienza e controllo sono i fattori chiave di questi prodotti.

I sistemi Smart Home Energy Management non solo forniscono agli utenti il controllo e il monitoraggio dell'utilizzo dell'energia, ma forniscono anche approfondimenti sull'utilizzo, i dati storici, le tendenze, le possibili possibilità di ridurre gli sprechi e, in definitiva, la possibilità di risparmiare energia e spendere energia in modo efficiente. Ciò è stato consentito da vari sviluppi tecnologici. In questo rapporto vengono esaminate le varie tecnologie utilizzate, la diffusione del sistema di gestione dell'energia della casa intelligente nel mondo e la sua diffusione. Dall'analisi dei dati esistenti è stato discusso l'attuale tasso di diffusione del Sistema di Gestione dell'Energia Smart Home e vengono brevemente spiegate le potenziali tendenze future. L'attuale tasso di diffusione tiene conto delle condizioni di mercato esistenti, delle aree geografiche, del canale di vendita, delle tecnologie e dei tipi di società sono discussi in dettaglio. Per avere un quadro più ampio, è stato preso in considerazione il mercato mondiale Smart Home Energy Management System.

Keywords: Smart Home, Energy Management Systems, IoT.

1. INTRODUCTION

1.1. INTERNET OF THINGS (IOT)

The Internet of Things (IoT) portrays the organization of actual article "things" that are implanted with sensors, software, and different advancements to associate and trading information with different gadgets and frameworks over the internet. These gadgets range from customary family objects to modern apparatuses. With nearly 10 billion associated IoT gadgets today, specialists are anticipating that this number should grow 22 billion by 2025. Internet in this century is assuming an indispensable part in our day to day routine particularly post Coivd19 pandemic. As a large portion of things has become virtual or on the web, even the schooling system, office, work, and so on, the internet become an undeniable component in human existence. One primary innovation or a result of internet is the IoT which empowers spry answers for each customary technique which are an aid. This innovation empowers the world to divide and trade data between one another independently and immediately where they are on the planet. Because of its certainty it has turned into a piece of each and every application which is leading to the development of brilliant urban communities. Home computerization as such is an application region where IoT is incorporated into a home making it shrewd. As IoT is being reveled wherever the interest for electronic devices is likewise at a quicker rate. As the devices are expanding, power consumption by a specific home likewise grows up which on an entire gives an enormous expansion in energy consumption thinking about the entire world. The energy expected to work the contraptions in home is provided from a power framework which used to work in a traditional manner for example just the energy stream used to be from the energy station to home yet not the other way around. Coming of current innovation has made brilliant network giving energy in a more astute manner. With IoT being arisen in each application which gives a bidirectional correspondence from gadget to capacity and as the need might arise to be served by dazzling the information from the servers and as well as gadgets. So presently the brilliant network likewise gives energy upon the interest of the client where energy protection might occur thusly lessening the weight on commoners furnished the entire framework is incorporated with IoT. There ought to be framework which monitors energy that is consumed by a specific machine in a home which thusly helps in assessing how much energy consumed in the entire month. Sensors are utilized which can keep an eye about the energy consumption of a specific electronic machine. An edge cutoff will be set which when surpassed cautions the client about

it. By this way client can have their own particular manner of assessing the energy consumption in their home. Straightforwardly the consumed energy in watts is accessible in the portable through Blynk application. These qualities additionally can be stored in the cloud for additional examination, in which specific month energy consumption is pretty much that assists the client with changing their energy utilization.

1.1.1. IMPORTANCE OF INTERNET OF THINGS (IOT)

Throughout recent years, IoT has become one of the main advancements of the 21st 100 years. Now that we can interface regular articles — kitchen machines, vehicles, indoor regulators, child screens — to the internet by means of implanted gadgets, consistent correspondence is conceivable between individuals, cycles, and things. Through minimal expense registering, the cloud, large information, investigation, and portable advancements, actual things can share and gather information with negligible human intercession. In this hyperconnected world, digital frameworks can record, screen, and change every association between associated things. The actual world meets the digital world — and they coordinate. As IoT turns out to be more far reaching in the commercial center, organizations are gaining by the enormous business esteem it can offer. These benefits include:

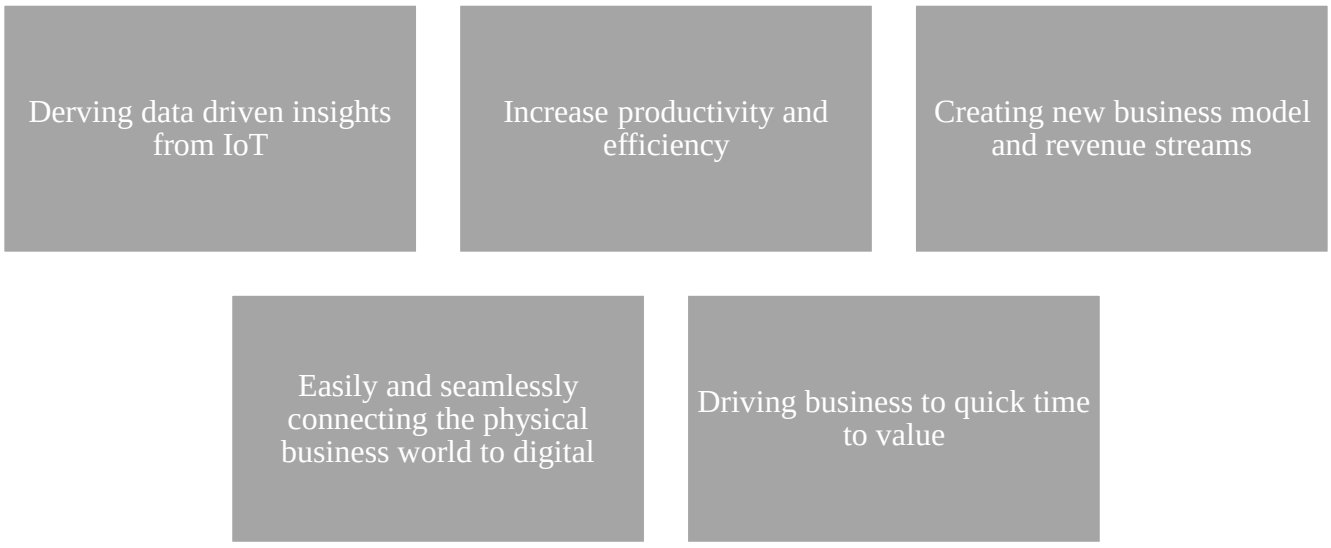

Figure 1 Benefits of IoT

The internet of things helps individuals live and work more intelligent, as well as oversee their lives. As well as offering brilliant gadgets to computerize homes, IoT is fundamental for business. IoT furnishes

businesses with a constant investigate how their frameworks truly work, conveying experiences into everything from the exhibition of machines to inventory network and coordinated factors tasks. IoT empowers organizations to mechanize processes and decrease work costs. It likewise eliminates squander and further develops administration conveyance, making it more affordable to produce and convey products, as well as offering straightforwardness into client exchanges. Accordingly, IoT is one of the main advancements of day to day existence, and it will keep on getting steam as additional businesses understand the capability of associated gadgets to keep them cutthroat.

1.1.2. TECHNOLOGIES THAT MADE IOT POSSIBLE

While the idea of IoT has been in existence for a long time, a collection of recent advances in a number of different technologies has made it practical.

Figure 2 Technologies that made IoT possible

- **Access to low-cost, low-power sensor technology.** Reasonable and solid sensors are making IoT innovation feasible for additional producers.
- **Connectivity.** A large group of organization conventions for the internet has made it simple to interface sensors to the cloud and to other "things" for proficient information move.
- **Cloud computing platforms.** The expansion in the accessibility of cloud stages empowers the two businesses and shoppers to get to the foundation they need to increase without really overseeing everything.
- **Machine learning and analytics.** With propels in AI and examination, alongside admittance to changed and tremendous measures of information put away in the cloud, businesses can assemble experiences quicker and all the more without any problem. The development of these united advances keeps on pushing the limits of IoT and the information created by IoT likewise takes care of these innovations.

- **Conversational artificial intelligence (AI).** Progresses in brain networks have brought Natural language processing (NLP) to IoT gadgets (like digital individual colleagues Alexa, Cortana, and Siri) and made them engaging, reasonable, and suitable for home use.

1.2. SMART HOME CONCEPT AND HISTORY

Smart Home is a complete arrangement that interconnects every one of the home exercises and the IoT innovations and frameworks to empower and make a far reaching agreeable, safe, energy saving home framework. As opposed to the customary home machines, the smart home frameworks energize the clients to start with and as a matter of fact after the establishment or use of those machines, the families are not able to return to the way of residing before the smart home presentation.

A smart home is a house that has internet associated gadgets which can do the administration independently and remote observing can be given to the inhabitants on lighting, warming, and so forth. Smart home innovation, likewise often alluded to as home automation or domotics (from the Latin "domus" significance home), gives homeowners security, solace, comfort and energy productivity by permitting them to control smart gadgets, often by a smart home application on their smartphone or other arranged gadget. A piece of the internet of things (IoT), smart home frameworks and gadgets often work together, dividing shopper utilization information between themselves and robotizing activities in light of the homeowners' inclinations.

From history, there is a consistent development in living of people. The design or state of the house was developing in a very long time, climatic changes and social transformation. At one phase, the house began getting divided for various individuals and exercises like resting, clean, work, kids, cooking, warehousing, and so on. Likewise, individuals began to get across the globe and begin living in different main lands, and areas. This century is giving more mechanical improvements that can be acquainted with the homes, in a way to such an extent that it can modifies the manner in which we live. For instance, the security of the passage was watched by the new strategies like camera, key locks, and so on to shield the house from undesirable or obscure access. Some of them gave video call as a visual check. Our passageways and lobbies have introduced control boards, where we can arm and open security, control molding, power, and deal with the arrangement of our homes. In the warehousing space, different mechanical molding has been utilized to keep up with the newness of the food sources or easy to stay away from natural dangers and parasite. Numerous gadgets were introduced in the kitchen to help the

washing, putting away and cooking. Gadgets have different control programs accessible to set a few activity modes for morning dishes, lunch, and supper. Such advances assist us with running our kitchen yet additionally have a great time during our day to day daily practice. Washroom and latrine are currently assisting us with keeping up with the vital degree of warm water, do clothing on time without recalling about it and backing us in clean and wellbeing. There are a few electronic brushes and complex clothing machines which have various accessible choices fitting our necessities. Our day rooms and offices are outfitted with further developed and complex hardware. Presently a PC or work area PC is a piece of standard hardware which we use for work, correspondence, and diversion. We pay obligations and purchase merchandise through Internet administrations, which decrease the time and assist us with monitoring all funds. Gadgets store data and act as information keep. Additional opportunities are accompanying the advancement of TV, telephone, and a few voice partners. We can now peruse data on the PC as well as on smart TV and our cell phone, which have similar limit as PCs these days. They make the association and thusly correspondence extremely simple and presently everyone can call loved ones or find support in peril from official administrations. Innovation even came to our rooms and youngsters' rooms. We have introduced temperature controls, humidifiers, carbon dioxin identifier, voice partner, and different sensors. Every one of them assist us with really focusing on our family and caution us in the event of peril. Innovation has come to our homes for good. What's more, late years got tremendous advancement applications in our homes. Houses go to speak with clients here and there by all hardware and software. As of late the Internet of Things (IoT) standard has overwhelmed electronic gadgets which are created to empower the Internet association and assortment of control choices through Wi-Fi, Bluetooth, radio-recurrence ID (RFID), neighborhood (LAN), and many directing conventions. Every one of them are accessible in PCs as well as TV, cell phones, Hi-Fi, clothes washers, clothing machines, coolers, coffee communicates, cooled, warmers and any gear which can work with sensors. Subsequently, we can notice a pattern toward universal innovation supporting us in a large portion of our activities at home, transforming it into a smart home. Practically every one of the parts of the life where there are innovations has seen a wide presentation of different smart home options like (lights, dishwashers, etc.). Examples of smart home technologies

- Smart TVs: Provides on demand video music content through internet even through voice and gesture recognition.

- Smart Lighting Systems: This enables the remote control and customization of lights in addition to which some of these lights can identify the occupants in the room and adjust the lighting as required. These lights can automatically adjust the lighting based on daylight availability.
- Smart thermostats, like Nest from Nest Labs Inc., accompany coordinated Wi-Fi, permitting clients to timetable, screen and remotely control home temperatures. These gadgets additionally become familiar with homeowners' ways of behaving and naturally change settings to give inhabitants greatest solace and effectiveness. Smart thermostats can likewise report energy use and remind clients to change channels, in addition to other things.

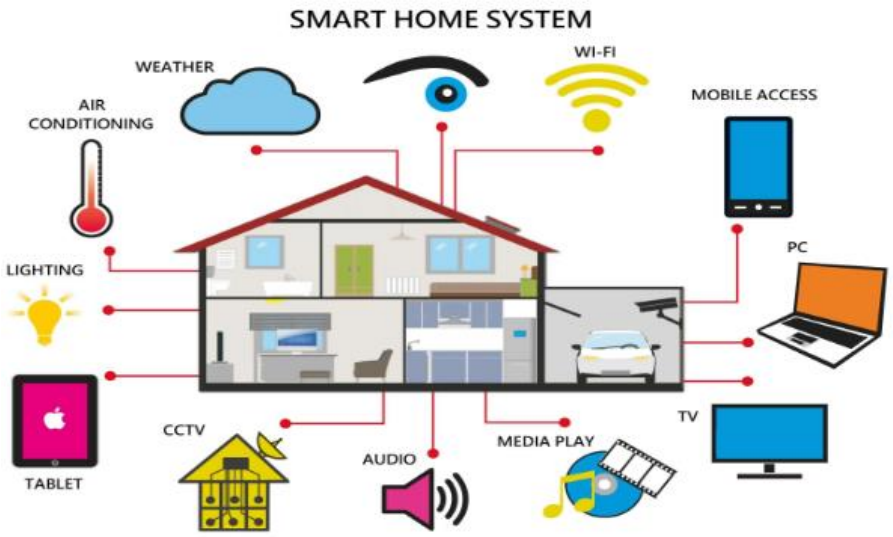

Figure 3 SMART HOME support in daily activities

- Utilizing smart locks and carport entryway openers, clients can give or deny admittance to guests. Smart locks can likewise identify when inhabitants are close and open the entryways for them.
- With smart surveillance cameras, occupants can screen their homes when they are away or an extended get-away. Smart movement sensors are additionally ready to recognize the contrast between occupants, guests, pets and robbers, and can tell specialists assuming dubious way of behaving is identified.
- Pet consideration can be computerized with associated feeders. Houseplants and yards can be watered via associated clocks.

- Kitchen appliances of numerous types are accessible, including smart coffee producers that can brew a new cup naturally at a customized time; smart coolers that monitor lapse dates, cause shopping records or even to make recipes in view of fixings as of now close by; more slow cookers and toaster ovens; and, in the pantry, clothes washers and dryers.
- Household framework screens may, for instance, sense an electric flood and mood killer apparatuses or sense water disappointments or freezing lines and mood killer the water so the cellar doesn't flood, for instance.

Nowadays, smart home structures and contraptions have become simpler to utilize and highlight the overall relationship to the clients. Web and IoT headways have been used to relate various devices (counting: temperature guideline, lighting frameworks, observation and security framework, sound and video gear, drape control, kitchen machines, cleaning, PC and correspondence hardware, morning timer, and so on.). Clients have some command over these contraptions to some degree through phones, tablets, and touchscreen sheets, extremely accommodating to manage between your everyday timetables, home machines and other sagacious home devices.

There are different headways and applications that can be presented in smart homes today anyway people regularly know practically nothing about what does they really need for their homes, similarly, foundation and high help cost are ending them to make the underlying step for smart dwelling.

1.2.1. SMART HOME RECENT DEVELOPMENTS

Smart home as one of the significant patterns in IoT improvement is introduced from different viewpoints both as a usefulness of the delivered innovation and most of potential advances.

- Heterogeneity: Separation of possible applications and frameworks which will be built to serve individuals at different necessities, support various information designs and host various functionalities.
- Self-configurable: the simplicity of setup is a significant element for individuals who are not innovation nerds.
- Context Awareness: the things that occur in the house should be connected with the setting of the everyday life.

- Usability: the elements of the home climate should be usable the framework will not give complex help assuming no one needs that except for help clients with those which they need.
- Security and Privacy Protection: data, information, and control can't be surpassed from an external perspective, the clients of the home framework should be protected from any assaults on their security.

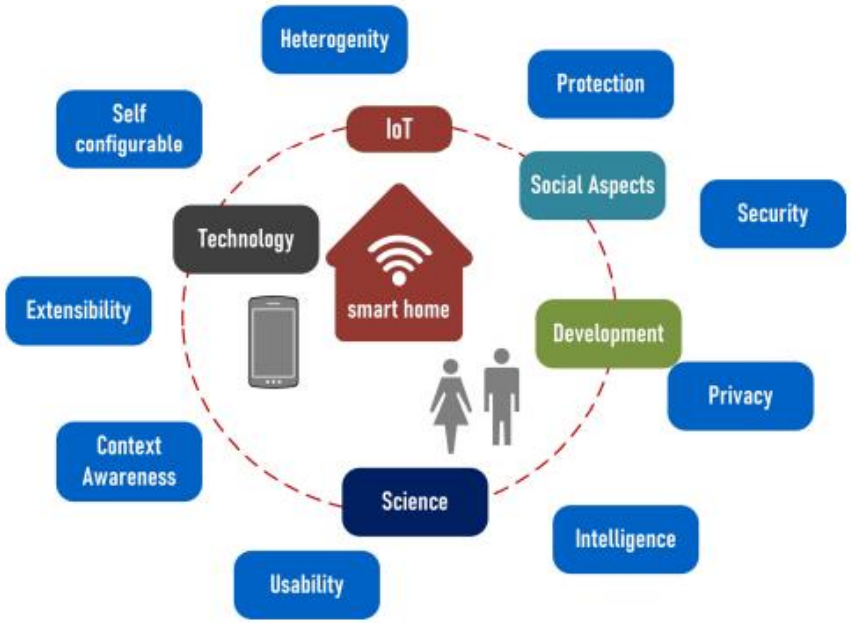

Figure 4 Expectation from the SMART HOME systems

- Intelligence: all apparatuses and software should uphold home clients by proposing essential activities and in any event, predicting the necessities of the proprietors which will be settled inside introduced parts.
- Extensibility: the new elements, gadgets, and software should be not difficult to add and cooperate with all yet working ones.

1.3. ENERGY MANAGEMENT

"Energy management" is a term that has various implications, however we're essentially worried about the one that connects with saving energy in businesses, public-area/government associations, and homes. Europe is focused on the 20-20-20 focuses to decrease fossil fuel byproducts and to supply secure energy. Energy proficiency and environmentally friendly power are viewed as key to arrive at these objectives. The two estimates for changes in our energy supply framework prompting smart lattices for the necessary development. The central design of organizations work in quite a while back has been created in most part states to address the issues of huge, dominatingly carbon-based age innovations. In any case, presently the organizations should coordinate decentralized and sustainable power age, likewise with numerous little providers. More adaptable vehicle of force is required in light of new energy markets and energy exchanging, and to the pattern towards area of mass age a long way from load. The European Commission has made various moves remembering an order for normalization for smart lattices gave in 2011. The last client with little source can possibly take part on smart matrix highlights and in this way ought to be involved and roused all through a few inspiration boosts. One of the critical highlights in the smart lattice applications is the interest side help offered to assigned parties by smart home automation frameworks. Energy management is a higher need than at some other time as associations desire to control costs, control energy and attract more young clients conscious about corporate social commitment. Unfortunately, various business offices and associations don't have their own energy chief or need automated deals with do a fundamental energy the leader's program. Business, industry and government affiliations have all been under huge money related and normal strains over the latest two or three years. Being fiscally vicious in the overall business place and fulfilling extending regular rules to decrease air and water tainting have been the huge driving components in most of the new practical cost and capital cost hypothesis decisions for all affiliations. Energy the leaders has been a critical gadget to help relationship with meeting these essential objectives for their transitory perseverance and long stretch accomplishment.

1.3.1. ENERGY SAVING MEANING

To clear a confounding subject, which is the vast majority use "energy management" to allude the energy saving endeavors completed zeroing in different energy saving estimates on the current structure and

gear. Rigorously talking, this is restricted to the conduct part of the energy management which is empowering individuals to lessen the energy utilization by making energy management mindfulness. Energy protection is the work made to decrease the use of energy by using less of an energy organization. This can be achieved either by using energy even more gainfully (including less energy for a consistent assistance) or by decreasing how much help used (for example, by driving less). Energy preservation is a piece of the possibility of Eco-sufficiency. Energy preservation measures (ECMs) in structures diminish the necessity for energy benefits and can achieve extended normal quality, public wellbeing, individual financial security and higher hold reserves. It is at the most elevated place of the commonsense energy requested movement. It moreover cuts down energy costs by thwarting future resource depletion.

Energy can be apportioned by lessening wastage and disasters, further creating efficiency through mechanical updates, and further created movement and backing. On an overall level, energy use can in like manner be decreased by the change of people improvement.

Energy should be changed beginning with one design then onto the following, similar to force energy to perspective power in vehicles, or dynamic energy of water stream to control in hydroelectric power plants. In any case, machines are supposed to change energy beginning with one construction then onto the following. The wear and contact of the pieces of this machine while running explanation mishaps of extraordinarily high proportions of energy and very high related costs. It is plausible to restrict these disasters by taking on green planning practices to additionally foster the presence example of the parts. On an overall reason energy efficiency works behind the scenes to additionally foster energy security, lower energy bills and attract countries closer to showing up at climate goals.

According to the IEA, some 40% of the overall energy proficiency market is subsidized with commitment and worth.

Energy Performance Investment are one subsidizing framework by which Energy protection measures can be completed now and paid for by the hold supports recognized over the presence of the undertaking. Homes and associations are completing energy-viability appraises that consolidate low-energy lighting, insurance, and, shockingly, inventive energy dashboards to slice bills by trying not to waste and lift proficiency.

Although, timer switches, etc., are very simple and cheap control equipment are also correct according to the definition, but mainly when energy saving or management is discussed it mostly refers to buying

new equipment or upgrading the existing equipment. When talked about energy savings it always and ultimately refers to money saved from it and the positive impact in creates in the society. When it comes to energy saving, energy management is the process of monitoring, controlling, and conserving energy in a building or organization. Typically, this involves the following steps:

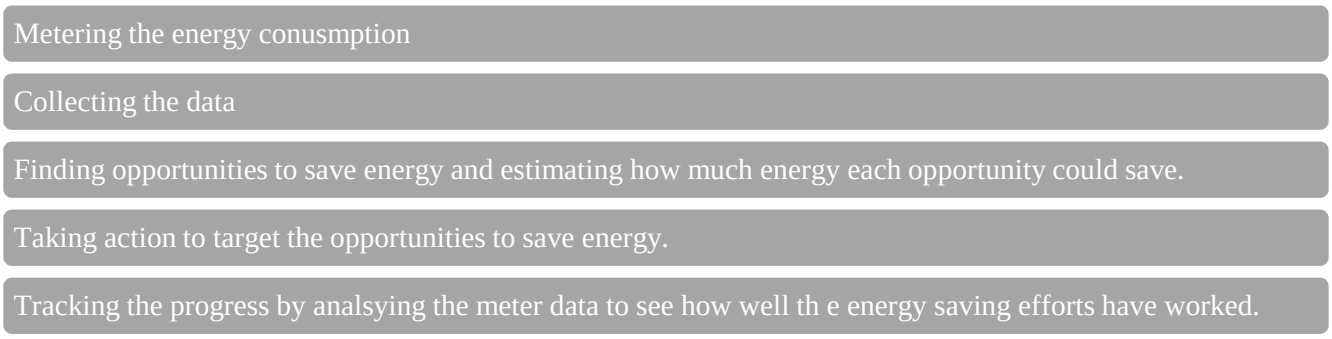

Figure 5 Energy saving process

1.3.2. HOME ENERGY MANAGEMENT

While energy management has been famous in bigger structures for quite a while, it has as of late begun getting on in homes. Most homeowners aren't even mindful of the term, and take to a greater degree an indiscriminate, stumbling along aimlessly way to deal with lessening their energy consumption. Be that as it may, the checking and results-driven approach utilized by professional energy directors is similarly however successful in the home as it seems to be in bigger structures. Thus, in the event that you're a homeowner hoping to save energy, don't be put off by the way that this article zeros in additional on non-private structures. The majority of the rules that apply to businesses and different associations are additionally pertinent to homes. Absolutely, the four-step process presented above and itemized beneath is actually appropriate to home energy management. A Home Energy Management System is a development stage included both gear and programming that allows the client to screen energy use and creation and to control or possibly motorize the usage of energy inside a family truly. Under the umbrella of organization configuration, Progressed Metering Infrastructure (AMI) devices have started a dependable correspondence mode interacting both power utilities and confidential clients. This correspondence channel prepared for an entryway to integrate the thoughts of financial inspirations conceptualized for a smart home for managing the interest side resource by changing to and from their energy use during top burden hours of the day as a strategy to shed load for reduced power

bills. The key part that allows all of the emerging Smart Grid advances to cooperate is the astute association between the organization overseers, utilities, besides, clients. The key objective of the use of HEMS is to engage the client to screen and control how much energy consumed or to consume it in a more compelling way. For this, the purchaser should know how the energy is being used in his home which should be enlisted when energy everything through the home is noticed.

1.3.3. SMART SOLUTIONS IN ENERGY MANAGEMENT

Smart energy arrangements contain contraptions like smart meters and smart systems that are used to gather critical data. This data involves limits associated with stream of force and can change from the introduction of gear to energy utilized close to the end buyers. By separating this information, an energy provider can make informed decisions to truly supervise power stream in every one of the three verticals of power age, transmission, and scattering.

Internet of Things expects a basic part in staying aware of the power stream in this large number of three stages. It is allowing the power associations to manage the load of force at even apex hours and reduce its wastage. Let dig profound into the benefits IoT offer in this huge number of stages. The electrical energy framework is right now going through a worldview change, that has been impacted by a change from the traditional centralistic and top down energy creation chain age, transmission, conveyance and consumption to a more decentralized framework, in which the members change their jobs progressively and communicate helpful.

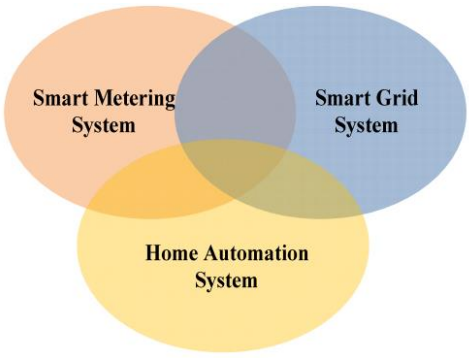

Figure 6 Various smart concepts in Energy Management

The improvement of the ideas and models for a European Smart Grid is definitely not a straightforward undertaking, since there are different ideas and designs, addressing individual partners 'perspectives.

The electrical power framework in the European Union depends on a major number of heterogeneous members that are close to one another associated. Each member of the electrical power lattice assembles and works its essential for the organization in its own way and simultaneously they need to cooperate. With the start of the 21st hundred years, increasingly more decentralized energy frameworks are coming into the organization once more, so future structures should uphold both concentrated and decentralized ideas. Therefore, necessities for conveyed and unified ideas and applications should be thought of. Smart meters and home automation frameworks in the idea of smart matrices Smart meters are the key empowering agent for smart networks accommodating two-way data streams between the meter and the assigned market associations. Smart metering frameworks might exist with regards to bigger smart lattice foundations and may coincide with home automation frameworks. Smart meters with regards to request reaction activities and smart home automation framework can be used as a passage between home organization and the WAN.

1.4. SMART HOME ENERGY MANAGEMENT SYSTEMS

The ongoing energy emergency has required critical energy decrease in all areas. The energy consumption in home regions has expanded as additional home apparatuses are introduced. Energy saving and sustainable power sources are considered as strategies for taking care of home energy issue. Both energy consumption and age ought to be at the same time considered to save the home energy cost. A few improvements of innovations in this field have brought about a more noteworthy effect in the smart home energy management framework market. Smart home Energy Management Systems exist on the lookout for quite a while.

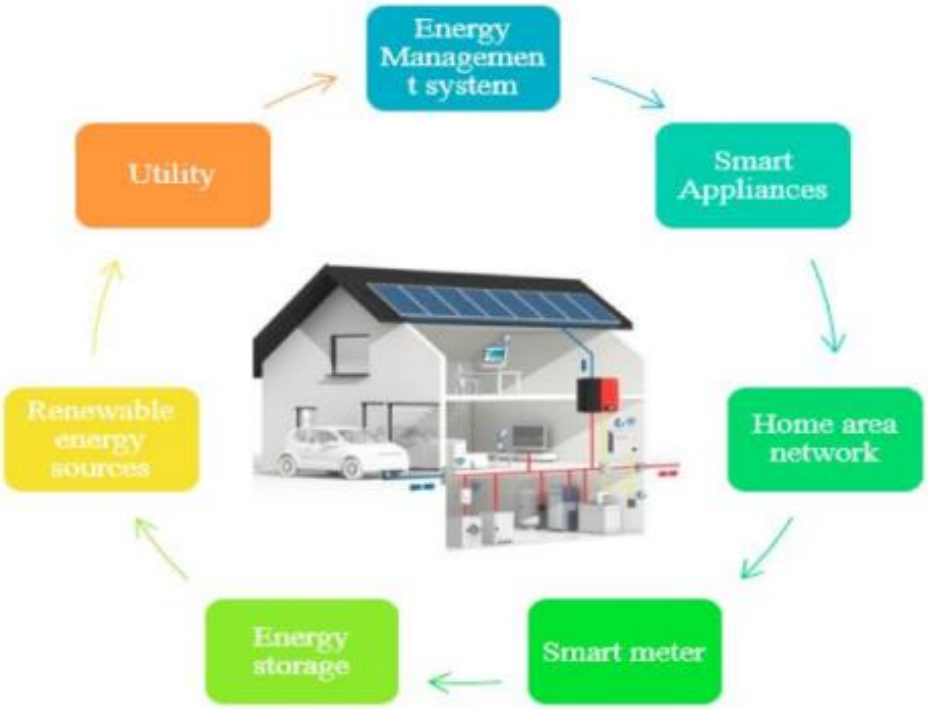

Figure 7 Elements of Smart Home

1.4.1. MAIN COMPONENTS

Energy management frameworks empowers the clients to go with smarter energy choice which at last can be made an interpretation of in to energy reserve funds and cost investment funds. Accordingly, it is exceptionally evident that the primary capacities of an energy management framework are controlling and checking. Checking permits to follow the energy consumption, normally at the circuit or gadget level. While an independent energy checking framework, an energy management framework gives the critical

added advantage of energy control-ordinarily at the circuit level. To be considered an energy management system, a system should have the following four key components.

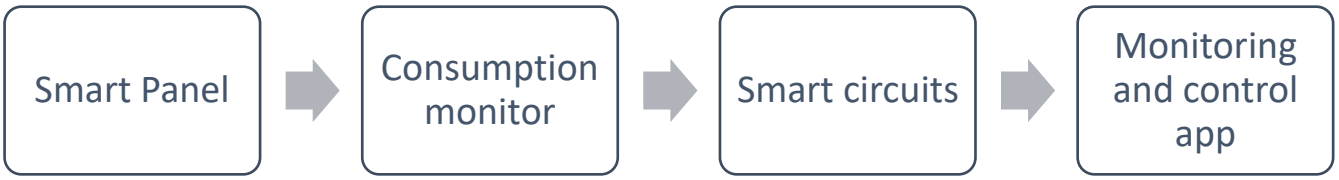

Figure 8 Main components of Smart Energy Management System

- Smart Panel: The smart panel is the heart of the energy management system and can typically take two forms: a replacement of the existing electrical panel (aka breaker box), or just an addition. Most of the smart panels are able to provide the consumption at circuit level, so the amount of power drawn from a circuit can be easily found.
- Consumption monitors: It is an integral part of the energy management systems, these monitors can take various forms and can measure the usage at different events, providing variety of detail and information. Additional monitoring devices can be added to provide the detailed data using various artificial intelligence and machine learning to understand the electricity signatures to provide the energy usage at device level.
- Smart circuits
- Monitoring and control app. Finally, the most important feature of an energy management system is that application or the app that allows the customer or residents to control and monitor the energy usage and performance, which is usually accessible via iOS, Android and web browser. Each app has different features and disadvantages. But in the end, it will provide the users with control over the basic functionalities. First and foremost, the users should be able to see how much electricity they're consuming (again, this can either be at the circuit level or at the device level depending on the consumption monitor). Even from the couch or travelling across the country, the residents will be able to control and monitor each circuit. Many apps will also provide with statistics about individual devices, including trends and costs over time. These components have a difference based on where these components are situated in the entire system. Whether they are situated at individual outlet in the house or at the top-level setup (such

as smart panel for the entire house). Each of these components can be combined according to the need to provide various solutions but collectively if all these are combined they are called the smart home energy management system.

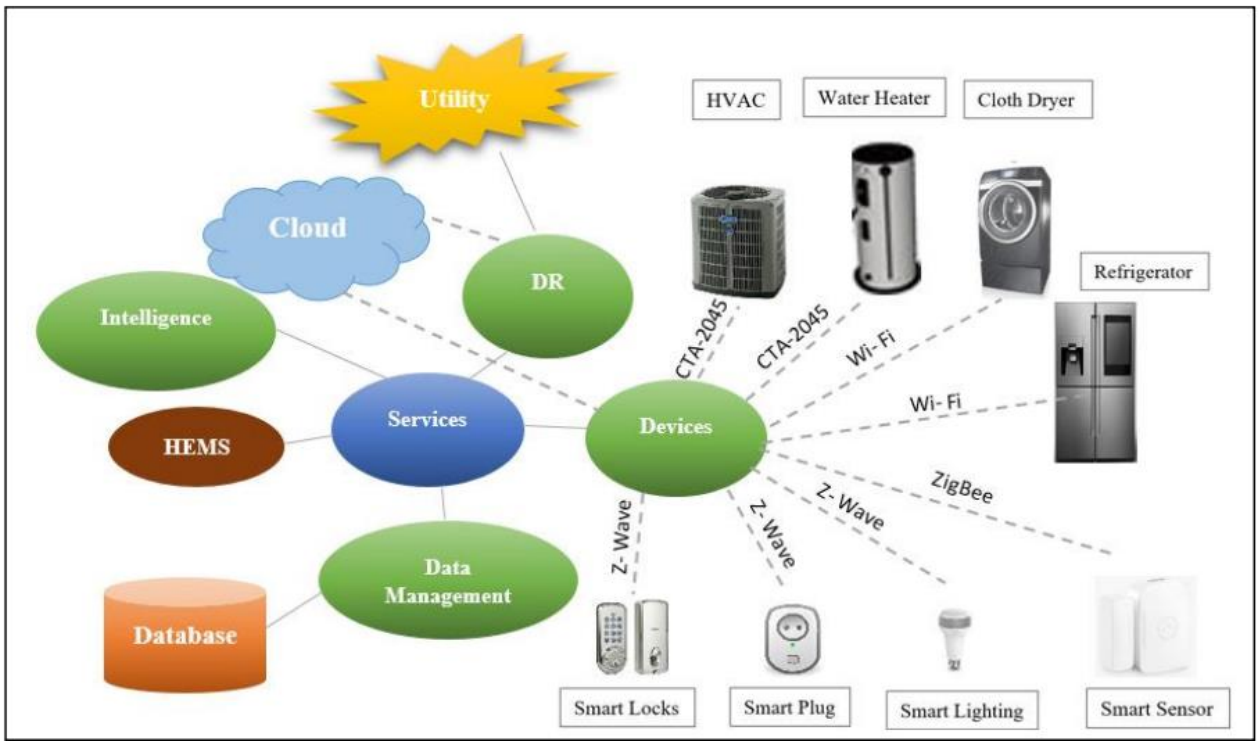

Figure 9 Smart Energy Management System Visualization

1.4.2. OTHER SYSTEM ARRANGEMENTS

The main enabling technologies of the smart home energy management systems are measuring devices, sensing devices, enabling IoT, smart appliances, and the energy management system.

Measuring device	Sensing device	ICT	Smart Applicances	Energy management System

Figure 10 Other system arrangements in Energy Management

Estimating gadget or unit are imperative to the Smart Home Energy Management System. For the most part it is the part of the Smart Home Energy Management System that actions the Gas, Water and power

which are commonly the meters in the families for estimating them. Most frequently, which can be estimated can be controlled also. The coming of Advanced Metering Infrastructure empowers estimation of nitty gritty, time sensitive data and successive assortment and communication of information to wanted objections.

The house hold senor or detecting units are exceptionally significant for the smart home energy management framework. This empowers are gives information about the current, voltage, temperature, light, inhabitance and movement. These sensors are intended to extraordinarily for detecting various things. Fundamental explanation for the plan of these sensors are wellbeing, wellbeing and security reason. Some of them are, smoke and fire sensor. These sensors measure the ideal boundaries persistently at better places and convey messages to the unified unit. With this information from the sensor, the boundary, smart machines, can be observed, planned and controlled.

The empowering ICT is the fundamental connecting pin associating the sensor, estimating unit and different gadgets to the focal unit that screens and controls. Different remote and wired correspondence advancements are accessible for coordination of different sensors and homegrown gadgets. WIFI, Z wave, ZigBee are the most usually involved innovation for associating the units to the control unit.

Smart machines empower inhabitants to figure out the genuine measure of utilization of energy, opportunities for energy productive arrangements and ecofriendly choices. These are the family items with inbuilt correspondence and knowledge frameworks that gives the inhabitants to remotely control and screen different boundaries. A portion of the current conventional domestic devices have become smart with next to no additional work for the private clients. Some of them are clothes washer, cooler, dishwashers, and so forth. These machines have proactively spread broadly without unequivocally realizing they are smart. These gadgets have inbuilt energy management frameworks that can consequently quantify and control different energy management boundaries giving more proficient offer to the clients.

The fifth part is energy management framework. To begin with, educational outline about the different realistic types of energy use information. Second, high level capabilities incorporate data, automation and control either locally or from outsiders. Third, coordinated frameworks with every one of the highlights of the high-level capabilities yet additionally incorporates the opportunities for estimating and

planning of burdens and neighborhood ages at family levels. At long last, robotized tasks give client determination to decide needs and will of the home gear and the neighborhood age of the activity.

1.4.3. FEATURES

From the study on the database prepared, the companies that provide the smart home energy management systems provides a wide range of features. Some of them are

- Monitoring and controlling energy usage of solar, Gas and water at a glance.
- Realtime and historical data via app and dashboards.
- Smart control and dynamic load balancing of electricity in houses.
- Interoperable with IoT products and services
- Cloud services to store the data and monitor the parameters anytime from anywhere.
- Various Machine learning algorithms to provide to provide timely and actionable information
- Artificial Intelligence and machine learning algorithms to identify problems, reduce waste, provide timely and actionable information. Ultimately reducing the cost spent on energy while making positive impact on environment.
- Historical usage and Realtime usage with estimation of cost of electricity bill.
- Smart plug radio for monitoring electricity with notification features, verification on connection in two way and encrypted communication.
- Integration of wireless communication technology enables utility meter to report data directly to the users through IoT system.
- Voice assistants, light and switch, speakers, camera, etc. connectivity to the available smart appliances.
- Energy efficiency of the devices.
- Scheduling and setting timer to avoid lamps, fans, humidifier, lights etc.,
- Provide control to switch on or off the devices from anywhere anytime.
- Smart notification that tells user if the battery of a device is running low.
- Suggestions and areas to improve the usage of energy or reduce the waste.

1.4.4. USABILITY

The features provided by the systems are provided in such a way that it requires very minimal amount of effort from the human or households. Such as

- Easy installation
- Low maintenance
- Over the air updates,
- Modular and future proof solutions.
- Low cost, etc.

2. OBJECTIVES AND METHODOLOGIES

2.1. OBJECTIVE

With the development of various smart devices that can improve the standard of living of human in every households also enables plenty of benefits to the society in a way of positive externalities. This gives rise to the focus on smart home energy management systems. Recently there are many developments in smart home energy management systems. These development enables the households, and the houses to monitor and control the energy usage easily. It also enables the support to the human in enabling the network controlling via responses, including peak saving, load shifting and with many additional services. These systems not only enable the monitoring of the energy usage of the house, but it also enables the residents to know the exact usage of energy by every device in the house, possible area of management or reduction of energy, or saving, etc. Due to the enormous features and benefits of the smart home energy management systems, there is a wide range of research going on in this field which is also due to the fact of the high diffusion of this technology across the globe. Many big players started offering their services in this market.

The aim of this paper is to study the entire market of smart home energy management across the world, understand their offerings, features, benefits and costs. This study can explain the idea on the amount of diffusion of the Smart Home energy management systems.

The answers for the following questions are the main work of this thesis:

- What is the state-of-the-art of Smart Home Energy Management System?
- What are the future trends in this market?

2.2. METHODOLOGY

To achieve the objectives of this report, and to provide a consistent analysis, the information is sourced from research papers and the secondary source which is the data base of the Internet of Things Observatory of Politecnico di Milano.

2.2.1.LITERATURE ANALYSIS

The first step of this research is started from the literature review of IoT application, smart home market and smart home energy management systems. This gives the information about the concept, history, technologies used, process and characteristics of the smart home energy management system in overall. This mainly provided the insight about the smart home energy management system state of the art and trend in various countries. This aspect of literature review also has been deployed for IoT and Smart Home systems. These research paper and academic materials are found on online databases for scientific purposes such as Scopus and Google Scholar.

2.2.2.SECONDARY SOURCES

It Is very important to remark that this report and research, to understand state of the art of the Smart Home Energy Management system, a database (Excel file) has been realized which was developed in collaboration with IoT (Internet of Things) Observatory of Politecnico di Milano, established in 2011. The aim of this observatory is to identify the state of the art of IoT applications, benefits, features, offers, trends and expected future development in IoT market across the globe.

The following section describes the parameters in the header row of the database. The data collected are used for analyzing the smart home market and understand the existing offers available in the market. The products and services are added to the database based on various variables, to understand the current market situation and future trends.

- **Company name** Information on the company name
- **Product/service name** Information on the product/service's name. In most cases, startups offer very few or one solution, because of this the company name and product name coincide.
- **Description**: Information of the specific product / service, mentioning the technical component along with the benefits for the user.
- **Geographical area:** This refers to the geographical area or continent where the company has its headquarters. The areas considered are: Europe, North America, Asia, Africa and Oceania.
- **Country** With respect to previous field, specific country information for that company is provided here.

- **Kind of firm**: The classification of the companies is divided in: Startups, SMEs (Small and Medium Enterprises) and Big Players.
- **Year:** If available, the year refers to the launch of the product in the market.
- **Physical device sale:** This column gives the information about the sales availability of that product or service. There are three possible options: already available, not available and soon available.
- **Presence of an App:** A vital detail to mention is the availability of an application connected to the product/ services to manage the solutions remotely.
- **Service** This field gives details about the service which is linked to the physical or hardware solution.
- **Service fee:** If the service needs an additional fee for the usage, and also the type of payment, whether it is yearly or monthly.
- **Channels** The possible distribution channels to deliver the customers of the solutions mapped are three:
    - **e-Commerce:** This refers to third party general e-commerce sales.
    - **Manufacture's website:** This refers to company's own website through which sale of the solution is carried out.
    - **Installers/ POS:** This refers to the sale of product by official store or professional installers.
    - **Retailers:** it refers to the sales in the retail stores. The products are physically available in the consumer electronic shops.
    - **Whole sale:** It refers to sale of product in whole sale stores. Typically, electronic consumer markets.
- **Presence in the manufacturer e-Commerce** This column refers to the possibility to buy the product/service from the website of the manufacturer directly.
- **Presence in general e-Commerce websites** This column refers to the possibility to buy the product/service from the general e-Commerce websites. In the next column is possible to indicate the names (e.g. Amazon or ePrice).

- **Presence in Italian Retailers** This column refers to the possibility to buy the product/service from Italian market and to report the names (e.g. Euronics, Mediaworld, Unieuro, etc.).
- **Pricing** The pricing system could be different from one product/service to another.
- **Sources** These columns are dedicated to the website's links from which information on the mapped solutions has been found. The source could be the company's website, a review, an article, etc.

The above database is a very resourceful database which contains the entire smart home products and services data. This includes Energy consumption monitoring, home appliances monitoring, ambient, lighting, smoke gas monitoring, etc. as their applications. To narrow down and focus on the main research topic of this paper, the database has been filtered out to only **Energy Consumption Monitoring** application scope. This helped the research to understand the existing situation of smart home energy consumption monitoring market, offers, features, services, across the globe. This results in a subset of the database with around **70 product/ service** listings coming from **46 different companies** based on North America, Europe and Asia. This list contains the product/ service listing that offers smart home energy management systems to customers either via Hardware and software or via both. This subset also contains the communication technologies available in those products/services, features, sales channels, etc.

3. SMART HOME ENERGY MANAGEMENT SYSTEM STATE OF THE ART

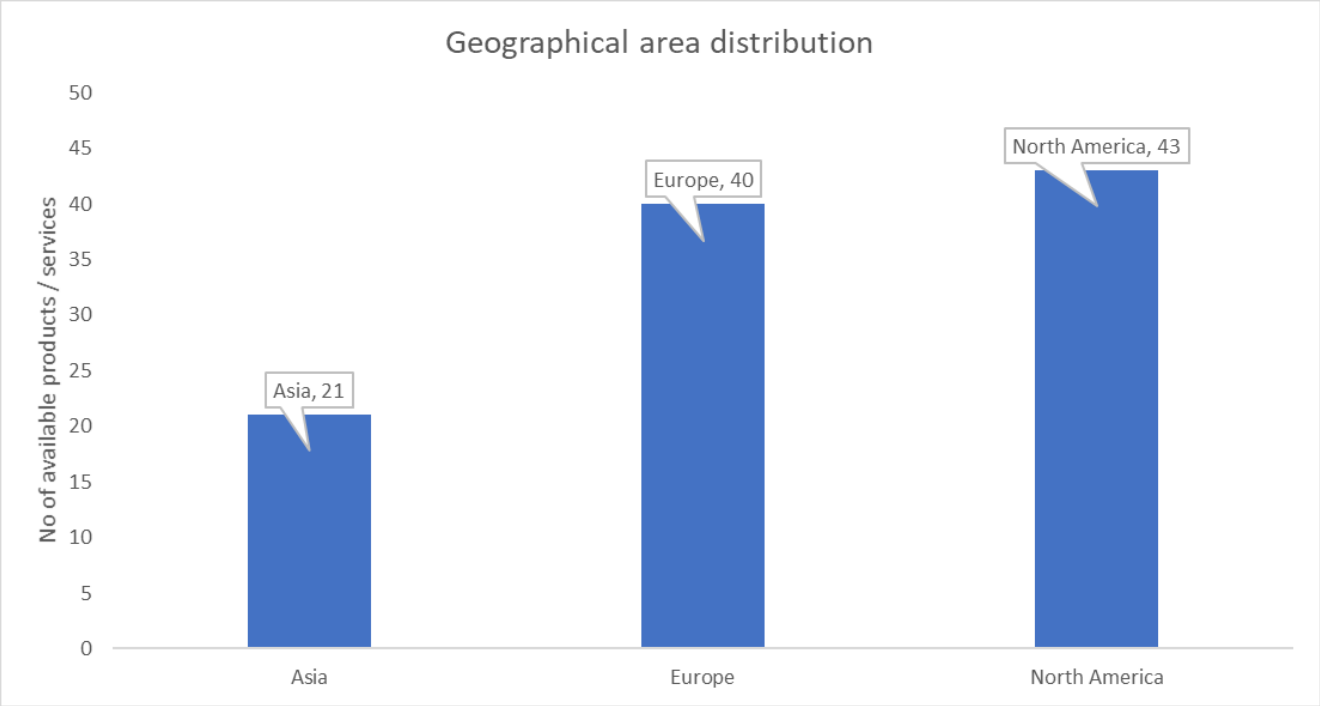

Figure 11 Geographical area where Smart Home Energy Management System are available

The number of smart home energy management systems available in the market can be easily split between 3 continents. From the above chart, it is very clear that the companies offering smart home energy management systems are present only in Asia, Europe and North America.

Comparing the number of companies in these 3 continents, it is clearly evident that North America and Europe have large number of companies offering smart home energy management systems which is nearly 40. In Asia, the number of sites offering the smart home energy management system are nearly 21.

Going deeper in to the data suggest that, research has to be focused to Europe and North America. The main reason for this rise in the offers in the Europe could be a main effect of European Commission's 20 -20 20 target, which is the 27 Heads of State and governments finally agreed to implement the 20-20-20 targets: by 2020, reduce by 20% the emissions of greenhouse gases compared to 1990 levels, increase by 20% the energy efficiency in the EU and to reach 20% of renewables in total energy consumption in the EU.

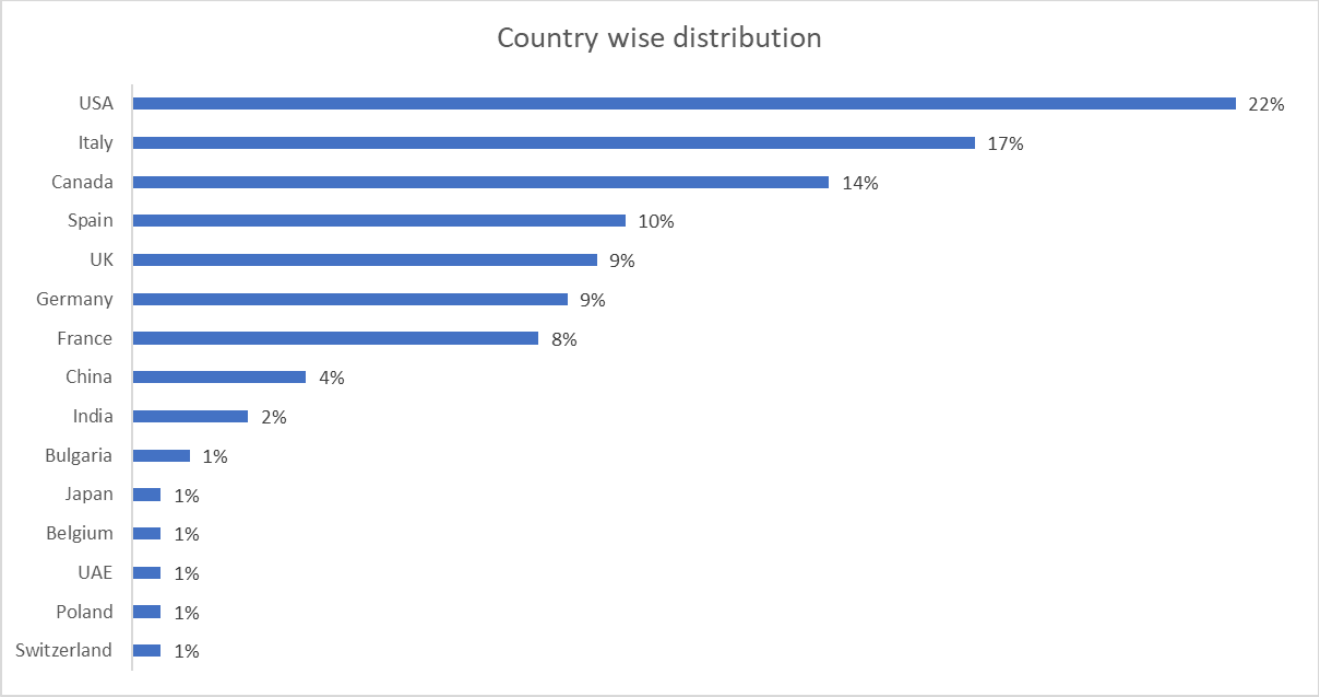

Figure 12 Country wise proportion where Smart Home Energy Management Systems are available

This country wise distribution tells how much the products/ services are welcomed in every country of the above discussed continents. As the chart tells, the companies providing the Smart Home Energy Management System in North America is very high in USA which is nearly 22% of the database.

On the other hand, in Europe, in Italy is the highest percentage of the companies providing the smart home energy management systems which is 17%.

Other nations of the Europe such as Spain has the next highest share of companies to provide the Smart Home Energy Management Systems referring to 10% of the companies and Canada in North America is base for nearly 14% of the companies. Nearly 9% of the companies provided the smart home energy management systems in UK and Germany respectively.

When taking about Asian countries, companies-based China and India are very low compared to the European countries which is around 4% and 2 % respectively. This also tells that the products and services available in European and American market for smart home energy management systems are very high than Asian market. This can be due to the slow adoption of the technologies by the Asian countries compared to the European and American countries.

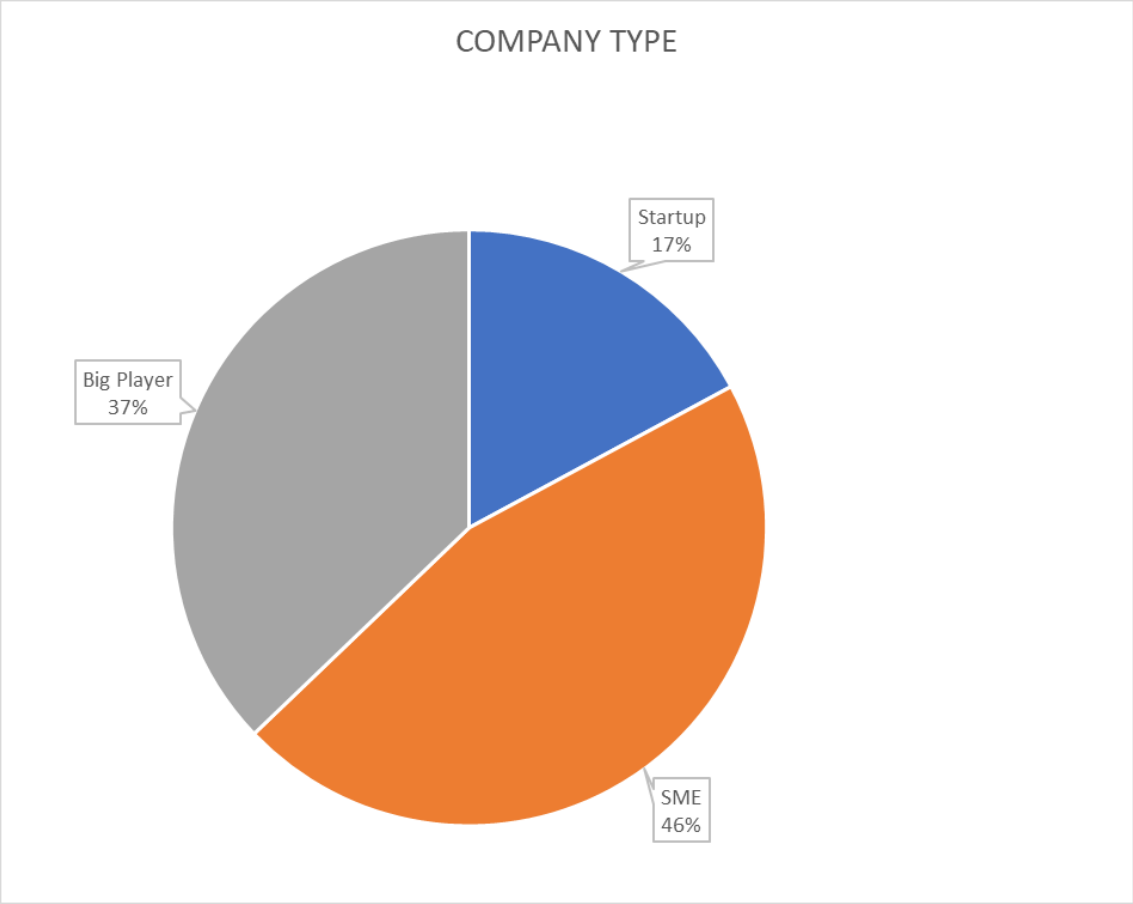

Figure 13 Company type that offers

Smart Home Energy Management systems market has become an interesting market segment in the recent decade. This motivated all players of different sizes to start participating in the smart home energy management system offering.

Also due to the increasing awareness of energy management among the people, organization and government, all types of firms from startup to Big players including SMEs started offering these services/products.

From the above chart, it is clear that SME's captured nearly 46% of the smart home energy management system market. Followed by Big players who has captured 37% of the overall smart home energy management systems market. The remaining 17% of the smart home energy management system market was captured by startups. There is an increasing trend in the startup players to provide these offering. This will be explained in the following graphs.

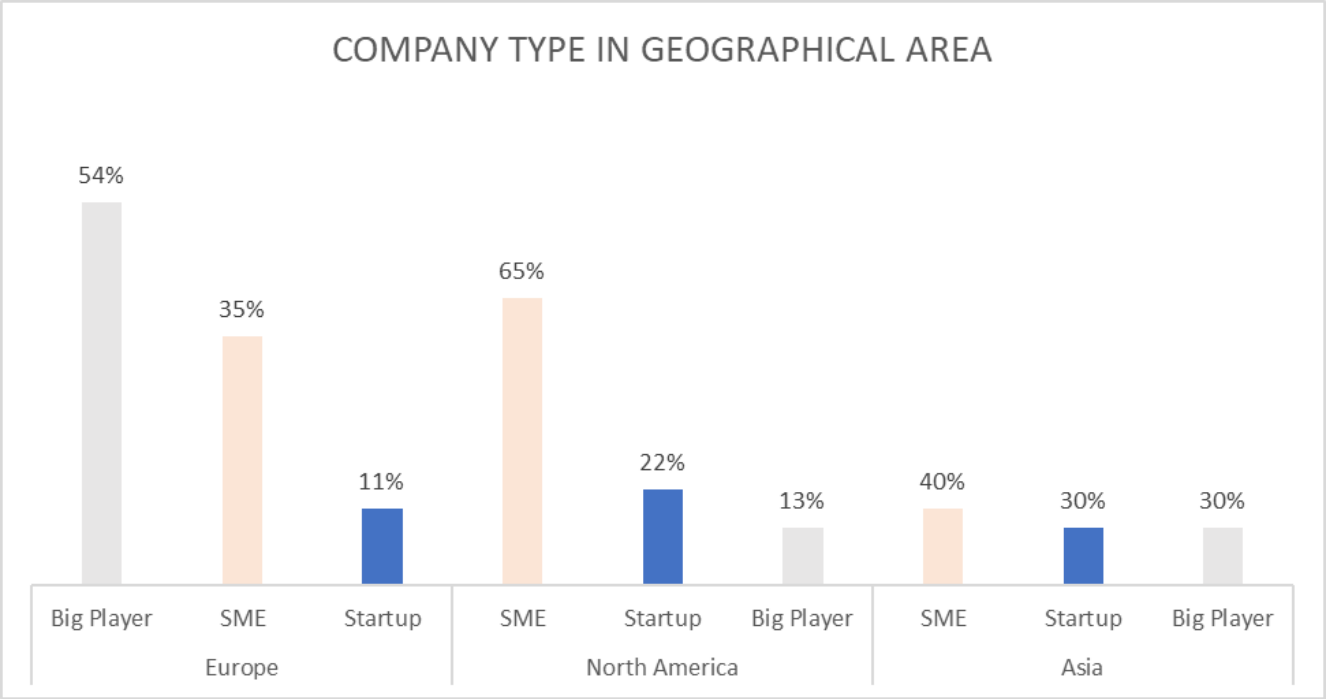

Figure 14 Company type across Geographical area

Various type of firms offers smart home energy management systems in various geographical areas. Different geographical areas have different shares of firm types. The amount and number of players from each firm type plays a vital role in understanding the market captured by different firm types. Since smart home energy management systems market has recently emerged all types of player are trying to provide more competitive offerings and services.

Starting with the European Smart Home Energy Management system, 54% of the European market is captured by Big player, where as 35% and 11% by the SMEs and startups respectively.

In case of North America, the majority of the market is captured by SME which is nearly 65% of the market and the remaining is captured by startup and big player at 22% and 13% respectively.

The Asian market is nearly equally captured by SME, startup and Big player with 40%, 30% and 30% shares respectively. This above graph also tells that SME's plays a major role in the Smart Home Energy Management offerings.

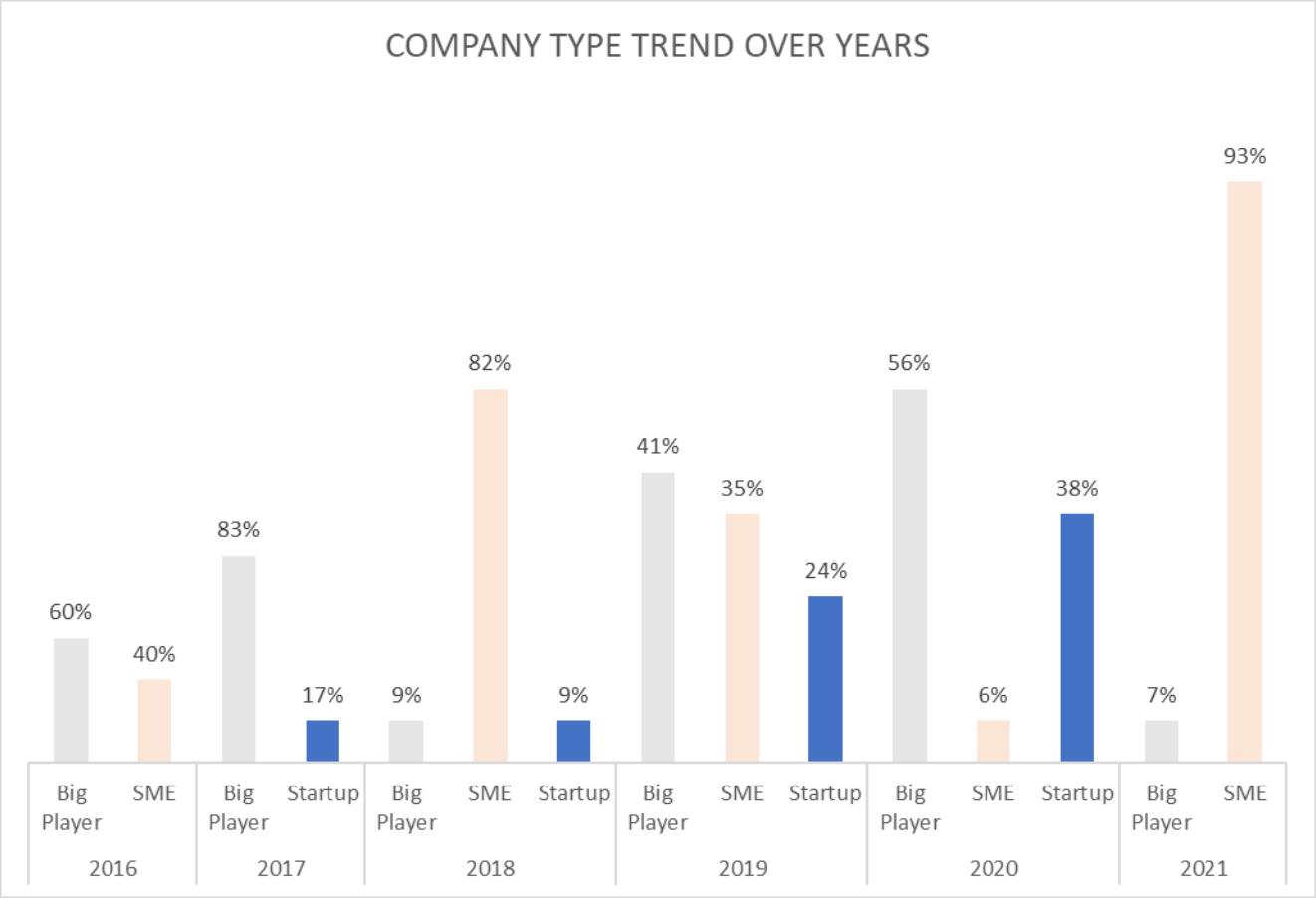

Figure 15 Company Type evolution

The above graph shows the evolution of firm types that provide the solution for smart home energy management. This evolution or trend shows many interesting things.

The graph also tells that, the big players offer of smart home energy management solutions odes not follow any pattern because in 2016, 60% of the solution are provided by Big player whereas in 2018 the share has been reduced to 9%. The share of big players started raising again in 2019 to 41% but dropped suddenly in 2021 to 7%. Various SME also started offering the solutions leads to the market share of 40% in 2016 and 82% in 2018 and 93% in 2021. Even though this trend is not linear, overall offer of solution by SME is increasing continuously.

From 2017, startup companies started offering the solution and progressively capturing the market share from 17% in 2017 to 38% in 2020.

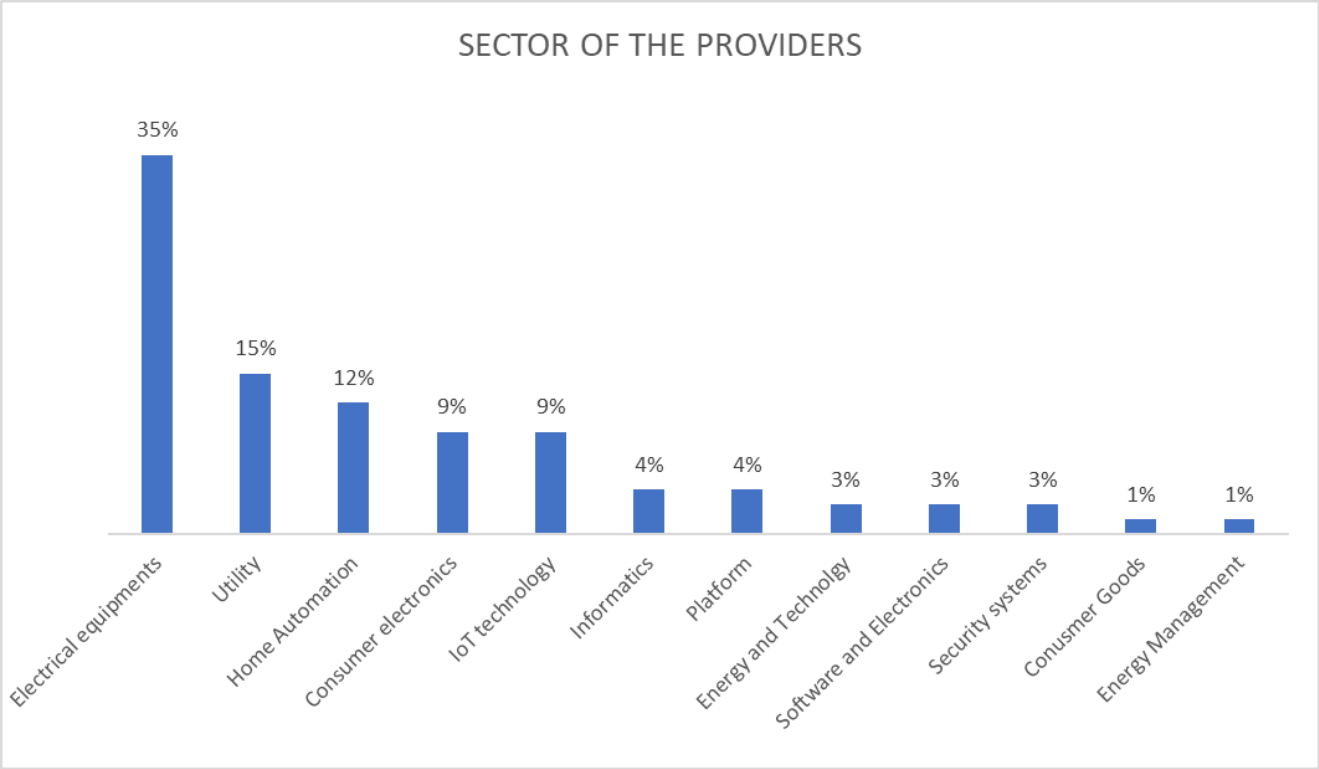

Figure 16 Sectors of the company that provides the service

Smart Home Energy Management System has become famous in the recent decade, which motivated companies from various sectors to produce and offer the smart home energy management products and services. The above graphs confirm this.

Companies from electrical equipment sectors provides nearly 35% of the smart home energy management system making that sector as the highest sector to provide the offers. Followed by utility sector which provides nearly 15% of the product and services.

Home automation sector player provide nearly 12% of the smart home energy management systems and 9% by the consumer electronics.

IoT technology sector players provide nearly 9% of the smart home energy management systems which also is very obvious as IoT plays important role in the operation of the smart home energy management system. Informatics, energy and technology, software and electronics provide 3% each of the smart home energy management system to the overall market.

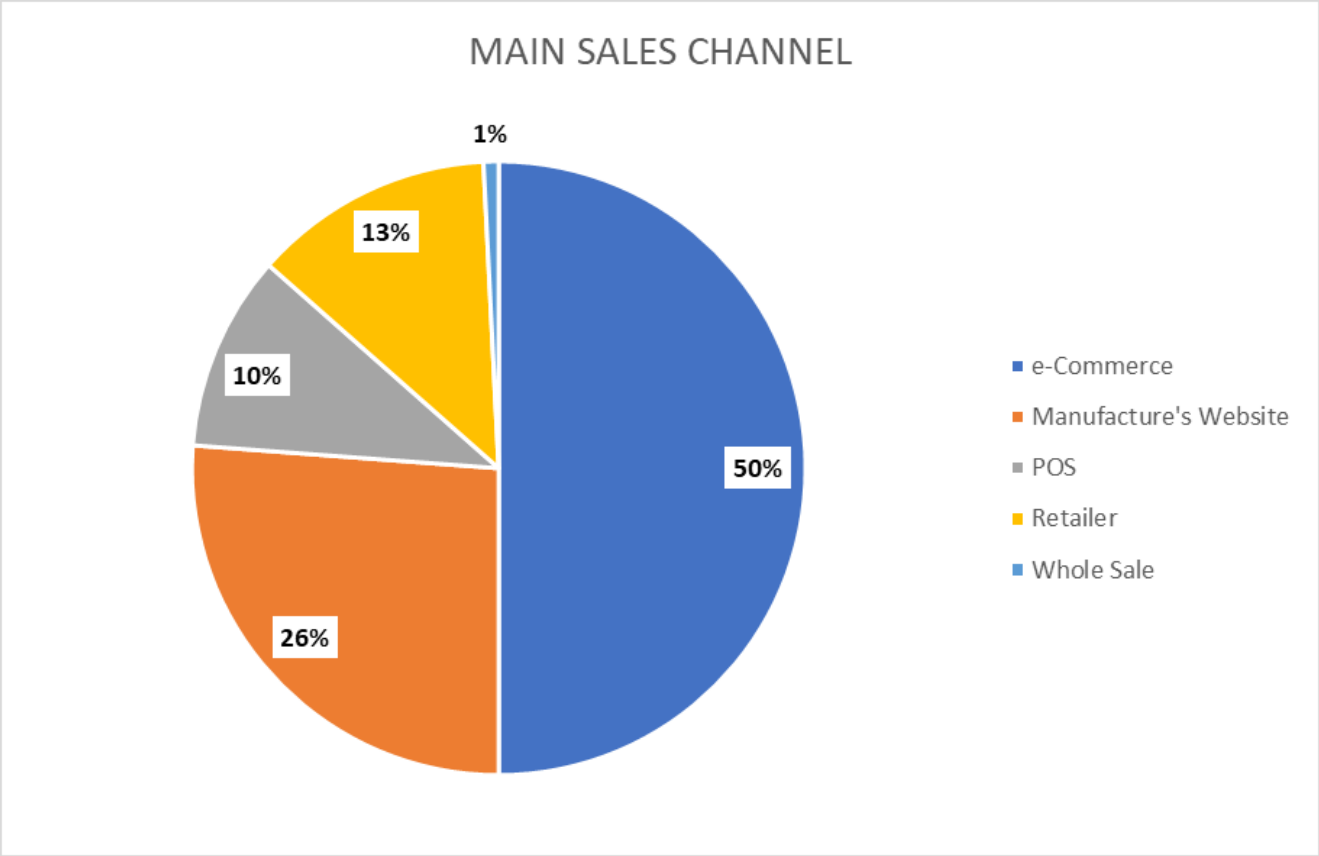

Figure 17 Main Sales Channels

Smart Home Energy Consumption systems are mainly sold through the above-mentioned sales channels. Such as e-commerce, manufacture's website, POS, Retailer and whole sale. Various product and services are available in more than one main channel such as e-commerce + manufacture's website, POS+ Retailer, etc. From the above graph, the most diffused sales channel is e-commerce which contributes to 50% of the sales of the Smart Home Energy Management Systems. Next main sales channel is the Manufacture's website where users can know the brand, features, etc. and this channel contributes to nearly 26% of the sales of the smart home energy management systems.

Point of Sale or direct showroom of the companies contributes to the 10% of the sales and the reason behind this could be the usage or adaption of new product in the market requires customers to study the product initially visually. Whereas retailer sales contributes to 13% of the sales of the Smart Home Energy Management Systems.

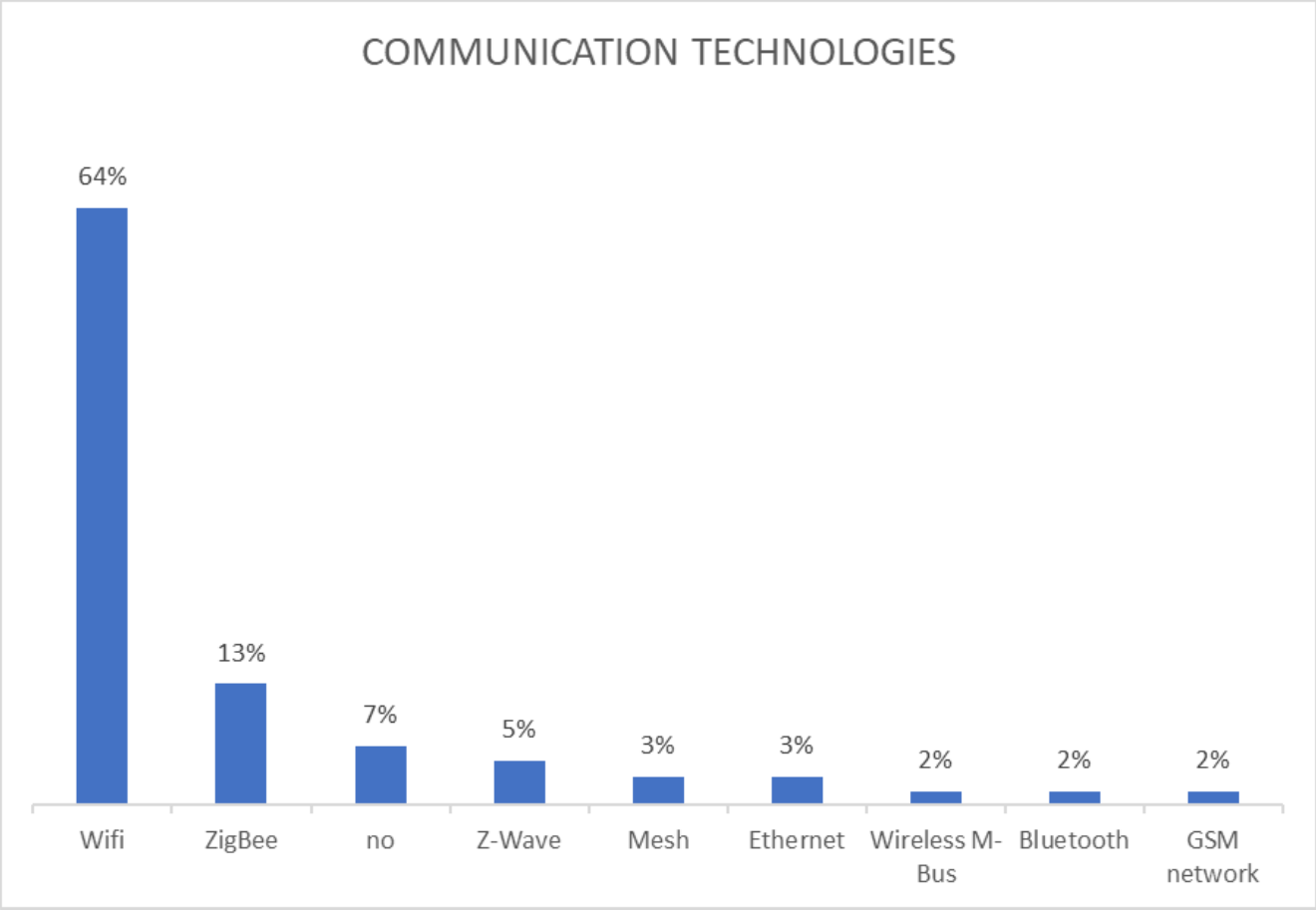

Figure 18 Communication Technologies

Communication technologies plays a vital role in achieving the goal of the smart home energy management systems. Usually various components are parts of the system measures, tracks, stores the data about energy usage from various points of the house or usage. To transfer this data and information, communication technologies are necessary. There are various communication technologies used in Smart Home Energy Management systems. Some of them are Wi fi, ZigBee, Z-wave, Mesh, Ethernet, Bluetooth, etc. From the data, it is very evident that Wi-Fi is the most commonly available communication technology in a smart home energy management system which is nearly 64% of the product/services.

Following that, ZigBee and Z wave are commonly available communication technologies which is around 13% and 5% respectively. Most of these technologies requires internet connection to transfer the data to the user.

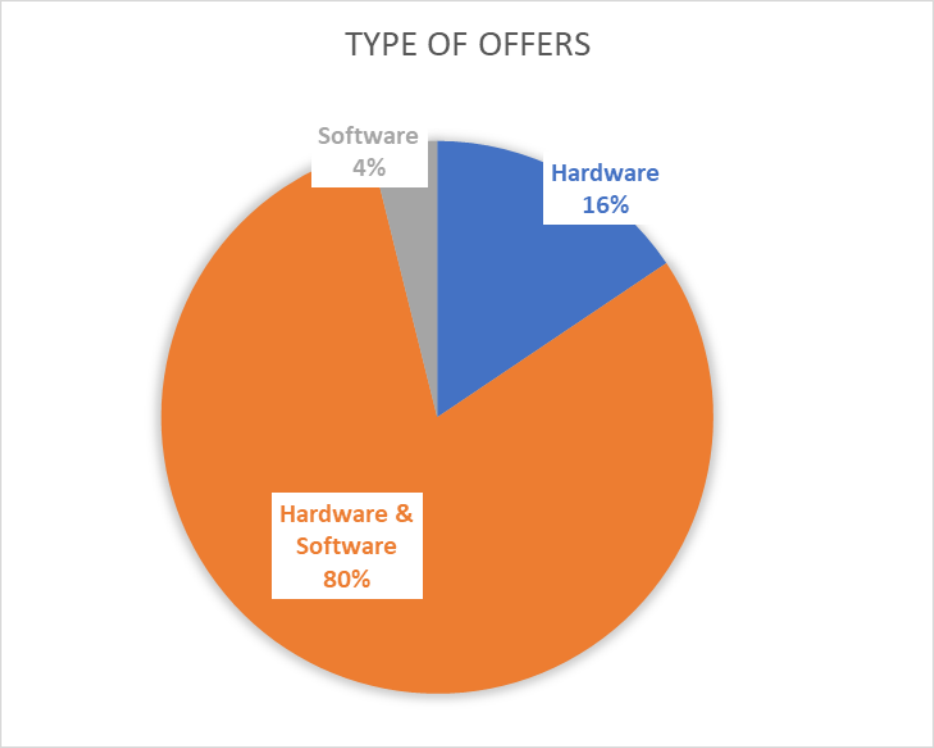

Figure 19 Type of offers

There are different kind of players in this market to offer product/ service to the people. When the type of offer provided by the companies are analyzed, it is very clear that most players offer both Hardware and software solution to provide smart home energy management system solution to the customers.

Nearly 80% of the player in the smart home energy management system provides both hardware and software together as the solution. When talking about hardware, in most cases it is a smart device such as smart meters, smart plugs, smart adaptor, smart switch, smart monitors, etc. which are applications of the IoT technology and can provide the expected result of energy saving. When talking about software, it is mostly an application that can communicate with the smart device and provide the smart information and control to the end user. With this combination of smart hardware and devices, the system is competed and provides the expected result where the user can check and monitor the energy usage. There are nearly 16% of the players that provides only hardware solution for smart home energy management system which are usually a smart meter which can help the user to monitor the usage of energy.

4. FUTURE TRENDS IN SMART HOME ENERGY MANAGEMENT SYSTEM

There are many trends that has the potential to impact the smart home energy management system in near future. Some of the very high potential trends are

- **Edge based Solution:** Offer of less reliance on the cloud, edge systems can provide more privacy and security for the users.
- **Wireless technologies:** The low cost and high-performance wireless technology availability has boosted the IoT development. New wireless technologies like Sidewalk are expanding smart home uses. Sidewalk is Amazon's new Sub-GHz solution, that enables extended range and network distribution similar to cellular. In Amazon sidewalk ecosystem, the devices are connected to the cloud using the Sidewalk- enabled gateways (i.e. smart home devices ranging from Amazon echo to floodlight cameras, ring doorbells, etc.) by leveraging the existing protocols.
- **AI:** Knowing, for instance, your constant energy consumption at home and dealing with ways of lessening it is the first and most significant stage. This beginnings with getting to live information and utilizing examination to help direction. The following part in the Smart Home's development will include making a layer of man-made reasoning to empower independent dynamic on a continuous premise. Simulated intelligence calculations can prepare a model, assess its own presentation, and make predictions. Whether we're discussing AI-empowered admittance control, predictive upkeep for HVAC frameworks or smart lighting sensors, headways in computerized reasoning present us with extraordinary chances to rethink the entire Smart Home idea. "Utilizing AI to decrease phony problems is a somewhat recent fad. Despite the fact that Alarm .com isn't the first, with Ambient Insights, it is the most recent instance of utilizing progressed tech to decrease deceptions and further develop client experience. These stages are additionally embracing more extensive use cases, like water, energy, security, and air quality".
- **Radar based systems:** Various radar-based systems have infinite opportunities, such as sleep tracking, occupancy in a room, fall detection and excess usage detection.

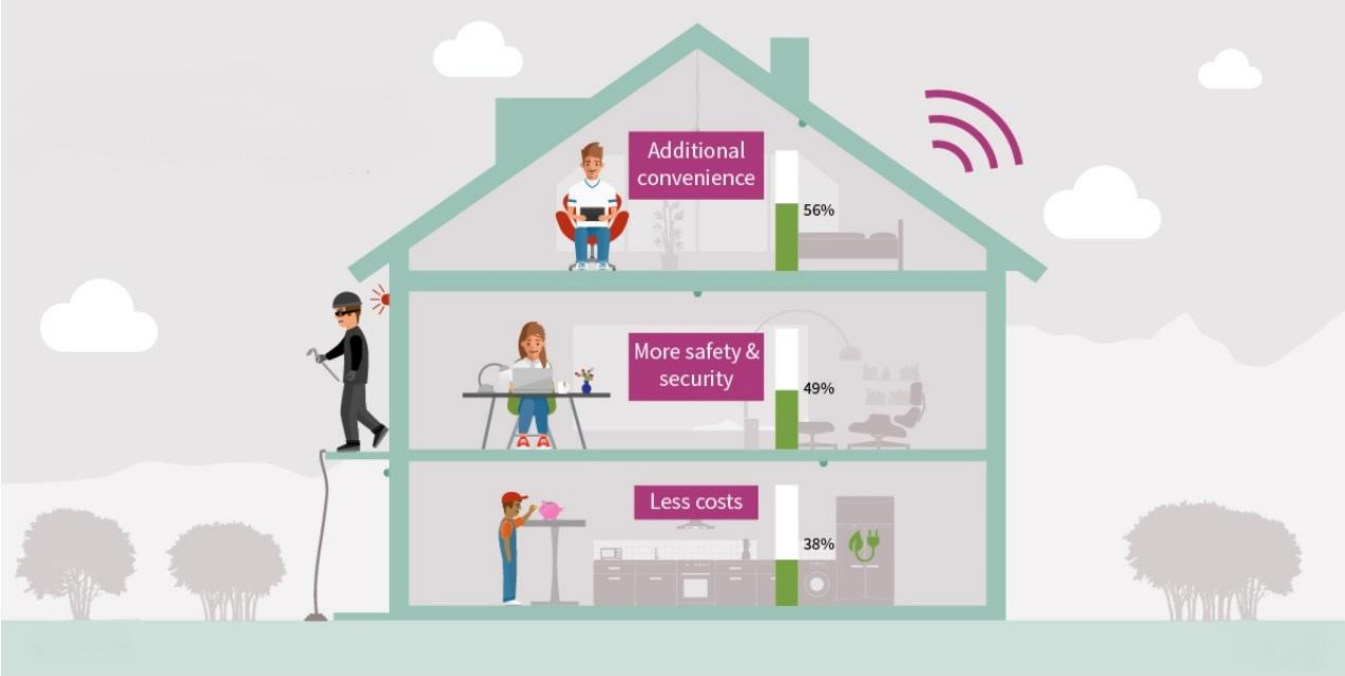

Figure 20 Future smart home

On the top of that, the main technologies trends in the smart home energy management system are mainly the trends of the smart home system. Some of them are

- **Integration:** The smart home devices are becoming fully integrated with all other devices in a house and even it has become as an expectation instead of luxury. This expectation also brings the complete connectivity in a house and ease of use.
- **Touchless tech:** The covid 19 pandemic has accelerated the companies to bring various touchless solution such as touchless hand sanitizer dispenser, etc. This expands the potential and the growth of touchless technology in various areas. Most of the smart devices are controlled by phone so the point of physical contact is already reducing.
- **Smart thermostats:** Smart thermostats are becoming one of the widely spread smart devices that has been effective in saving the energy effectively. Nest (a smart thermostat) player has claimed that their US customers are able to reduce their heating bill up to 12% and cooling bills up to 15% annually respectively.
- **Health tech:** Health trend started spreading rapidly which resulted in various solutions like air quality monitor, humidity monitor, smart air purifier, smart doorbells that can check the body temperature of the guests before entering the house, smart water filtering systems, etc. All these

systems are smart which means the users will always get the control of the device usage, energy consumption, etc.

- **Privacy features:** Most of the smart home energy system providers uses the cloud technology to offer the service and solution to the customers which also tells that, there is a potential for data theft. Thus, the focus on this is becoming vital in these years and companies started developing solution to overcome this.
- **Smart Kitchen appliances:** Various smart utensils like smart microwave, smart cooker, etc. which are able to provide the households to check and control the temperature of the food being cooked with a phone app. This also provides the customers with voice assistance, auto switch off, etc. These devices reduce the energy usage by avoiding the waste of energy while cooking and providing correct amount of heating or energy based on the food type.

Some common trends that support the market are high speed internet connection, various advancements in IoT technology and AI.

5. CONCLUSION

From the analysis of smart home energy management market, it is evident that this market is continuously growing and various trends are in progress in different countries. From the offers from different kind of players, it is also clear that more and more companies from various sectors are focusing this market.

The greatest number of solutions comes from North America which is a proof that the most of the people in these countries are early adaptors. Nevertheless, the number of solutions from Europe is also very high and almost near to the North America. This can also be a result of various government initiatives in the energy saving sectors. USA and Italy have the highest number of Smart Home Energy Management solution compared to all other countries. When talking about European market, European market is captured mainly by Big players whereas the North American market is captured by SMEs. The presence of startup players in this market has an increasing trend from 2017 till 2021. The main channel used for sale of these solution is e-commerce.

On the other, there are various emerging trends in the smart home market which give raise to expectations in terms of high security, privacy, speed and accuracy. These trends are result of Artificial intelligence and machine learning algorithms developed in recent days. Ultimately the result of existing technology is the high control and efficiency on usage of energy.

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