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Internet of Things as a Sustainable Energy Management Solution at Tourism Destinations in India

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Abstract: The development of tourist destinations has been determined by sustainable energy management and the advancement of traditional methods. The rate of development must adapt to technological innovations while also considering future generations. The present study aims to determine to what extent tourism personnel are aware of the skills, knowledge, and methods for sustainable energy management, and also to analyze the Internet of Things as a technological solution for sustainable energy management at tourism destinations in India with the help of the Servqual method. It is important to implement modern technologies such as internal things and develop a sustainable attitude toward tourism. Findings suggested that over each attribute of Servqual model, reliability, assurance, tangibles, empathy and responsiveness of IoT as sustainable energy management solutions at tourism destinations in India, tourism stakeholders have higher level of expectations (23.41, 19.86, 18.45, 23.60 and 24.73) and perceptions (18.34, 16.50, 14.97, 18.17 and 19.20) followed by tourists expectations (22.10, 17.36, 16.01, 22.62 and 21.87) and perceptions (19.32, 11.75, 09.46, 15.06 and 17.43) and local residents expectations (20.17, 14.61, 14.87, 19.46 and 18.81) and perceptions (13.48, 08.85, 07.73, 13.54 and 12.94), respectively. Results also showed that older generations and traditional tourism destinations are unable to cope with the modern advanced terminology, tools, and management strategies, which makes the present study the most significant about changing the traditional way of energy management and developing tourism destinations as sustainable and responsible.

Keywords: IoT; sustainable energy management; servqual method; tourism development

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1. Introduction

Over the last couple of years, the number of applications and devices that are operated by IoT networks has just doubled (approx. 8.4 billion in 2020 over 4.2 billion in 2018), passing through the number of the world's population [1–8]. Different researchers defined the concept of IoT in various ways based on the variety of technologies being used for a variety of purposes. In a wider sense, the Internet of Things can be defined as an ecosystem wherein various objects (things) are integrated with multiple sensors that facilitate communication with each other and with main computers without having physical interaction with the user and suppliers via different wireless modern technologies and network solutions [9]. Furthermore, researchers defined IoT as similar to K. Ashton's original approach, which claims that the Internet of Things is a comprehensive and complex system where materialistic objects are equipped and integrated with sensors that collect information from the environment in the form of signals and communicate to users' computers with the help of internet networks (teleinformatic) [10,11]. Moreover, for connecting IoT with tourism destinations, there is a need to meet certain criteria, i.e., embed network sensors in devices and applications that are looking after tourism products and services. These devices and applications must have a microprocessor by which a device becomes connected to the internet. With the help of standardized communication protocols, devices and applications gain access through connected networks [12–14]. IoT devices have complex sensors connected only to main control applications or radio frequency identification (RFID) tags to identify and track their position through other devices and control systems [14]. Destination devices are operating through IoT control networks, having faster-growing network segments, and usually have two parts: tourists (to whom the information about destinations is presented) and service providers (tourism planners, hoteliers, and ground handling agents) [15–18].

The seventh goal of sustainable development goal (SDG) proposed by United Nations is also targeted to eliminating poverty in energy sector [19]. The sustained and continuous efforts are needed both at the national and international level to realize the importance of global access of energy in all the sectors including tourism and hospitality [20–22]. Therefore, the development of new applications, technologies and systems such as Internet of Things (IoT), coupled with governmental practices, policy making, and social transformation at tourism destinations, is needed to enhance afford-ability to tourists, local residents and tourism stakeholders with rapid local, regional and global access of energy resources [23–25]. To ensure energy access at all tourism destinations at large scale, comprehensive planning, equal distribution of available resources and use of decentralized grid systems approach will bring significant changes in the present situations. SDGs related to energy are shown in Figure 1.

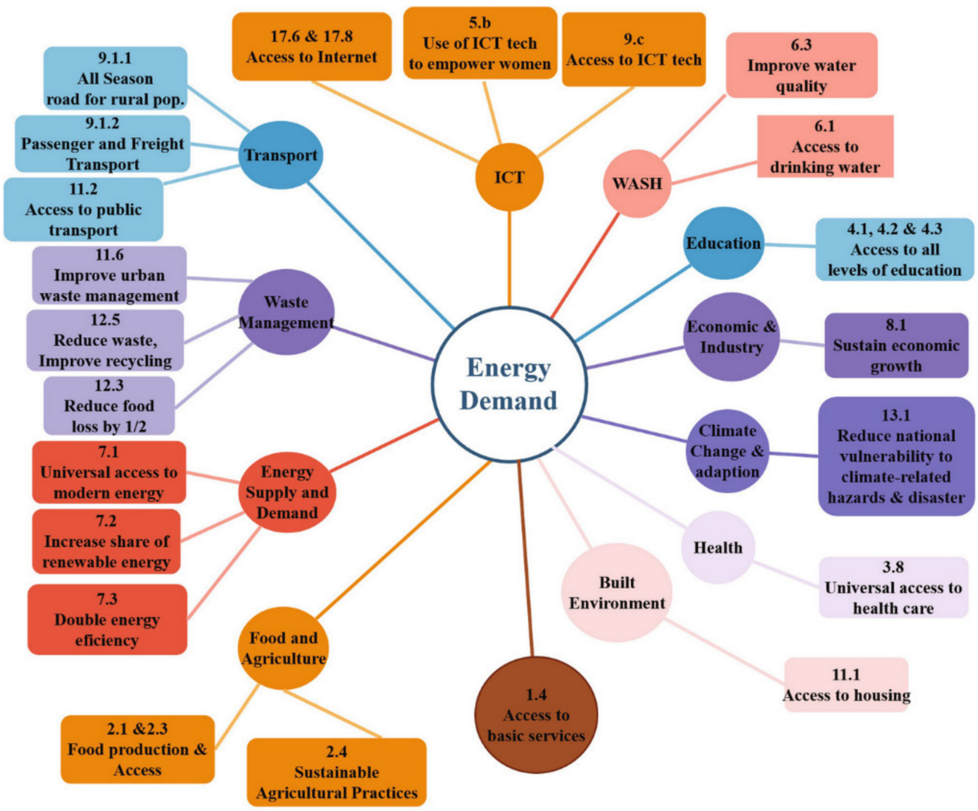

Figure 1. Energy Related SDGs at Tourism Destinations, (https://link.springer.com/chapter/10.1007/978-3-030-35291-2_6) (12 February 2022).

Previously, it has been observed that energy demand at tourism destinations in India increased substantially and shown strong and direct connection with sustainable development goals (SDGs). The energy access is highly correlated with sustainable tourism development and economic, socio-cultural and environmental satisfaction of tourists, local residents and stakeholders through following attributes: betterment of health facilities and destination education via dependable energy infrastructure [26–28], supply of clean water and sustainable energy [29–31], promotion of agri-tourism through energy drives [32], development of transportation system by using new energy resources, services such as cooking, electric lighting, household heating and cooling are require energy and tourism products and resources are also relies on sustainable energy management.

The sustainable energy management [33] has the significant potential to reduce negative impacts of tourism destinations and energy inequalities. The International Energy Agency (IEA) has defined the sustainable energy management as: a destination having reliable and most affordable access to both destination facilities, and to electricity, which is enough to provide highest level of perception and satisfaction to the tourism professionals. Presently, more than one billion people across the world do not no access to electricity in their houses and workplaces. The absence of sustainable energy management is impacting more to the remote areas and offbeat tourism destinations across the globe [34]. Ever growing world population has been predicted that outrun of the energy resources and access will lead several critical problems in the later future [35]. The present expansion of the energy sources will play a vital role to meet demand of the tourism destinations in view of carrying capacity of the destinations. However, there is a strong need to discover new energy sources, with sustainable tourism destinations in India. To discover the cost effective and productive sustainable energy management solutions such as Internet of Things (IoT) [36–38] is also important for economic, socio-cultural and environmental growth of tourism destinations. The sustainable energy management is also useful to reduce cultural conflicts, ecological imbalances and gender inequality over the tourism destinations across the globe [39]. Over-tourism causing mental and physical stress in tourism professionals at destinations [40,41]. Therefore, it has become most important and necessity of time to use the IoT as a tool for sustainable energy management solution in tourism and its associated sectors. The sustainable energy management has tremendous socio-economic and environmental benefits to the local communities, tourists and stakeholders in terms of improving destination satisfaction index and developing responsible and sustainable tourism. The UN's sustainable energy management solutions for all [42] are focusing on well-being present and future generations. Likewise, the tourism destinations are also in need of management of tourism products and resources via sustainable energy management solutions, and present research work is one of the serious attempts towards this through IoT as a complete and comprehensive solution. The sustainable energy is required by all the tourism stakeholders at destinations for operating their businesses smoothly, infrastructure development, tourists' safety and security, advancement of healthcare system and other necessary touristic amenities and facilities. Moreover, there are certain challenges being faced by destination management organizations (DMOs) and destination management companies (DMCs) towards management of potable water and wastewater treatment systems due to lack of energy access and unstainable management of available energy resources. Therefore, sustainable energy management is becoming the top priority of the destination planners, policy makers and tourism stakeholders for making tourism destinations responsible and sustainable in India. The significant gap between demand and supply of energy at tourism destinations in India has also been observed, and in order to fill this gap, the Internet of Things (IoT) would play a vital role, thus the present study has been conducted. Furthermore, the projected growth in energy demands up to the year 2040 is shown in Figure 2.

For the present research, tourists, residents, and different tourism stakeholders have been interviewed to investigate their expectations and perceptions towards IoT as a sustainable energy management solution at tourism destinations by using the multidimensional research instrument SERVQUAL (a standardized scale for measuring service quality) developed by A. Parasuraman, Valarie Zeithaml, and Leonard L. Berry in 1985.

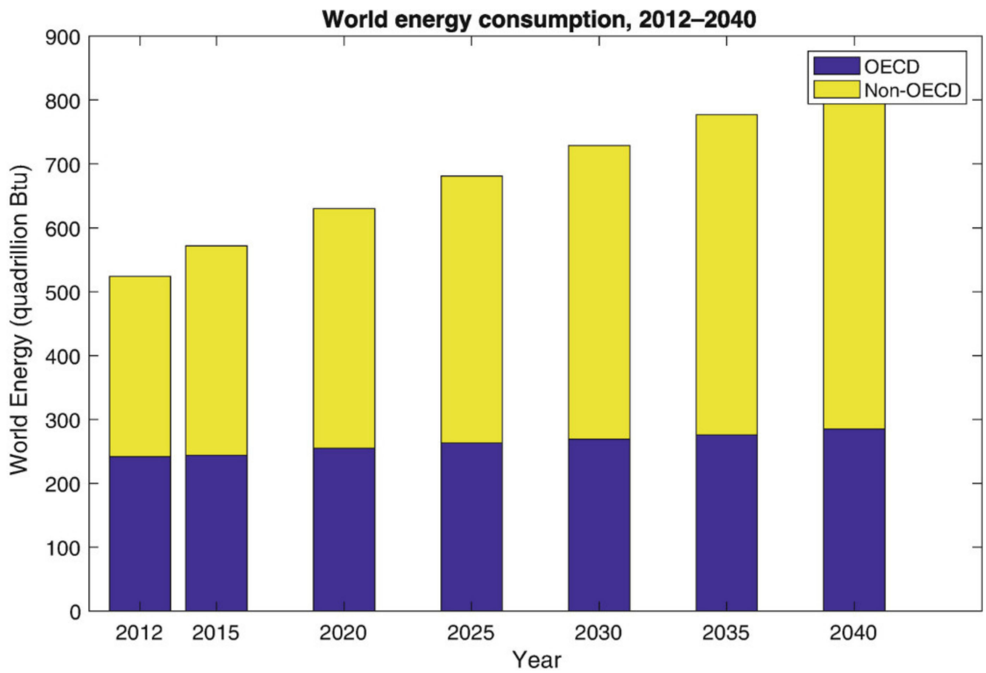

Figure 2. Projected growth in world energy demands up to 2040, (https://link.springer.com/chapter/10.1007/978-3-030-10427-6_1) (12 February 2022).

2. Literature Review

Sustainable Energy Management (SEM) is the process of combing different management skills with an understanding and knowledge of responsible energy resources at tourist destinations and also ensuring sustainable development of various sources of energy (e.g., geothermal, biomass, wind, solar, hydro, etc.). The IoT describes a wide range of internet platforms that have evolved into real-world applications and are used in routine and daily lives. These could be machines, products, equipment, etc., which are located at different and remote locations but well-connected with each other virtually. Such objects and devices, working as physical connecting points and cyber systems, are monitored and controlled by cyber systems [43–45]. Technically, the IoT has the capability to self-configure itself with the help of standard and interoperable protocols as this is an active network infrastructure [46]. IoT recognizes all entities as "things" which have fundamental physical properties such as tangible characteristics, online existence, and intelligent interfaces and are also connected through online information systems [47,48]. Since all things in the system are well-connected and communicate with each other and perform seamless integration under cyber-physical interface through IoT [49]. An IoT system is made up of a number of components, including processes, security, business models, a network of connections, and announcements [50,51]. Various other factors, such as extensibility, scalability, and interoperability, play a significant role while designing the IoT architecture and in the smooth transition and integration of heterogeneous network devices under supply chain management [52,53]. A typical service-oriented architecture (SOA) of the IoT comprises [54,55]:

- This hardware (Radio Frequency ID, actuators, and sensors) layer is being used to sense, collect, and control physical systems and data.
- The networking layer integrates and communicates information across each other, and also provides necessary networking support and data transmission among all the entities.
- The service layer provides functionality to IoT services and applications by generating and controlling services and underlying technologies.
- Interface layer: Ensure effective interaction between users and other applications in virtual space.

RFID is an important technological system working towards the IoT, facilitating and broadcasting information to end-users under a secure network system. Other methodologies and technologies that have been adopted by the IoT are intelligent sensors, barcoding, internet protocols, applications, and embedded devices [56–58]. The RFID system is majorly used in industries such as electric power plants, logistics, warehousing, the service industry, retail, etc. [59–61]. These days, IoT has become inevitable and top-preferenced among technologies due to the nature of firms and organizations, and hence, the below-listed techniques in Table 1 are on the priority list of the industries. IoT is an innovative, transformative, and disruptive technological system that is significantly influencing the present and future of various industries and organizations via different means such as productivity, profitability, and optimization of resources [62,63].

The trends of the IoT are far-sighted, unique, and reach out to all major industries, businesses, and sectors. However, diffusion and perceived adoption are in a nascent stage. There is still a gap between awareness and acknowledgment of IoT concerning adaptive strategies and knowledge management for the maximum utilization of resources and benefits to customers and people in remote areas [64,65].

Table 1. Technologies of the Internet of Things.

IoT Technology	Description
IoT Security	Trillions of devices and machines become connected and interact via IoT systems across the globe, increasing the chances of data mismanagement and misuse [66]. Around 21 billion IoT devices are expected to be installed by the end of 2021. This could be the primary reason for cyber-attacks and data thefts [67]. Therefore, instant actions are required regarding security, trustworthiness, and standardization of IoT security systems.
IoT Analytics	Voluminous or big data having a variety of needs requires analysis through algorithms and modern analytical techniques of IoT in real life [68].
IoT device management	Industries and businesses must have the capability to manage and align millions of devices and machines connected through IoT [69].
Low energy IoT networks	IoT significantly helps in saving energy and electricity and it is estimated that low-energy networks would be the most preferred along with wireless IoT connectivity by 2025 [70].
Low Power Wide Area Network	A network such as Narrowband IoT (NB-IoT) is also an important component of the IoT space, and it has the potential to ensure high-speed communication, coverage, and high electric battery life [71].
IoT Processors	IoT Processors provide robust security and encryption solutions, low power utilization, energy-saving solutions, and also support firmware operative systems according to demand [72,73].
IoT Operating Environment	According to their systems and setups, the IoT provides the most appropriate operating environment for organizations [74,75].
Distributed Stream Processing	Multiple platforms are needed to support and connect distributed streams for managing and analyzing data in real-time operations with the help of parallel computing architectures [35,36].
Platforms	There are various platforms for IoT infrastructure systems, which facilitate efficient planning, processing, controlling, and managing of devices and machines via data acquisition, computing, storage analysis, and sharing policies [18,50,51].
IoT Standards and Ecosystems	Communicability and interoperability are the two main unique features of the IoT programming interface systems, standards, and applications [76].

As we know, the last half-century belongs to and was fully dominated by information communication and technology (ICT), but that is also true that electric power and energy systems (EPESs) will dominate the coming several decades. It has been in the limelight and in a dominating position since the global economic crisis in 2008 [77]. However, the climate change agreement signed by the name of the "UN Climate Change Conference (COP21)" in Paris in 2015 was the real cause of the transformation in EPESs [54]. Improving the productivity and reliability of electric power network operations; energy conservation; reduction in carbon emissions; distribution of renewable power supply sources; and increasing efficiency are the important transformations that have been carried out by EPESs with the help of IoT [78]. Furthermore, in making transformations and innovations towards intelligent electric power networks, IoT plays a crucial and integral role. Intelligent electric power networks are must-needed networks for saving electricity, which include supervisory control and data acquisition (SCADA) and advanced metering infrastructure (AMI). Presently, IoT technologies are working on such networks [79,80]. There are uncountable uses and benefits of intelligent electric power networks after integrating with IoT, such as [81–87]:

- Enhanced energy efficiency, adaptability, reliability, and resiliency.
- Protocols for communication and energy transmission have been reduced in number.
- Networked operations and chain systems enhance the operational capabilities of electric plants.
- Improved control and management of home appliances, resulting in rapid end-to-end service provisioning.
- Enhance the sensing abilities of various devices and applications.
- Improvements in interoperability and scalability.
- Reduced frequency and severity of natural disasters.
- Reduced physical attacks such as substation break-ins on EPESs through regular real-time monitoring of electric power networks and systems.
- Reduce your consumption and save energy.

Electric power generation infrastructure becomes dominated and transformed with DER solutions. IoT could enhance the efficiency of the entire DER system for saving electrical energy. Therefore, DER systems must be integrated and deployed in all power generating stations to manage and control operations, portfolio design, optimization, siting, and maintenance. Power generation networks of the IoT are the most reliable, affordable, durable, and safely accessible sources of power [26]. For effective utilization and optimal balancing of intelligent EPES operations and a portfolio of electrical power plants, it is necessary to monitor and manage the process of transmission and distribution of electric power network systems [88]. This would help in developing new customer-friendly and energy-saving IoT devices and machines such as microphase measurement units (PMUs), PMUs smart meters, and intelligent feeders [30].

Presently, electric power T&D networks are facing various challenges such as DER integration, power losses, data thefts, and delayed outage response times. Digitizing and transforming existing electric power T&D networks with IoT could help alleviate the challenges. These could be accomplished through the IoT's intelligent monitoring and control capabilities. Existing electric power T&D networks could operate well and effectively manage problems related to power outages, customer satisfaction, and DER integration. Additionally, IoT could also help in reducing power losses, conservation of energy, avoiding data thefts, and improving transmission and distribution by reconstructing several electrical networks and parameters such as phase, voltage, power, and current. Electric power T&D networks are more reliable and useful when they link with IoT devices such as distribution electric power network sensors, ADMS, smart meters, and inverters, which also ensure optimal utilization of energy without wasting it [89].

Proper management of electric transportation and distributed energy systems is crucial to saving and storing electric energy for future use. This could be made much easier through IoT devices and sensors. Digitalization of electric power consumption through IoT ensures customers' satisfaction with electricity costs, effective utilization of electric power, and reduces power wastage. It also helps in maintaining greater flexibility, scalability, better control, and enhanced reliability [13]. IoT batteries and EVs play a significant role in controlling fluctuations in power generation. If it falls below the demand, these batteries and EVs are also provided to supplement the power supply. Innovative pricing strategies [64] and innovative business models must be implemented by the IoT value chain because of the utilities and saving maximum energy [7,90].

These smart and innovative home occupancy sensors for the IoT would help monitor all kinds of movements in and around the customers' houses, thereby protecting the network devices and houses from criminals and vandals. These devices and sensors also save electrical energy and reduce its wastage by controlling and managing the entire power system virtually through IoT smart home occupancy sensors such as closed, open, motion, and perimeter sensors [91].

By using IoT smart home environment sensors, customers could create and maintain a comfortable and pleasant living atmosphere inside the house [92]. These IoT smart sensors are customized and installed based on temperature, humidity, leak, water, smoke, air, and light [93].

These IoT sensors monitor the power and keep an accurate record of energy storage and consumption at home [94]. Using these smart sensors and power monitors, customers can manage and monitor their energy usage more accurately and effectively, adjust according to requirements, reduce energy wastage and ensure proper utilization of home appliances and other devices. These power monitors are instant readout monitors (e.g., Blue Line Power Cost monitor), circuit by circuit measurement monitors, readout and history monitors (e.g., Wattvision power monitor), and plugin monitors (e.g., Kill a Watt EZ electricity monitor), with both history tracking and instant readout capabilities (e.g., eMonitor) [95].

Some other IoT smart home sensors that are currently available on the market are dry contact sensors, current transformers, smart plugs, power synching sensors, smart home monitoring kits, and AC/DC voltage sensors [96,97].

With the help of the extensive and intensive review of literature, it has been found that IoT is a very important, complete, and compressive tool for saving energy in various ways through managing customers' knowledge about different devices, sensors, networks, and techniques of IoT.

Despite the growing number of publications and research on the Internet of Things, there is no single consistent definition of it. According to Porter and Heppelmann, the phrase "Internet of Things" was created to "reflect the situation in which the number of smart, connected products is growing and to emphasize the new opportunities that they may bring with each other" [98–100]. They describe this concept in more detail [78]. Namely, they define the Internet of Things as "sensors and actuators embedded in machines and other physical objects, which have been used to collect data, remotely monitor, make decisions and lead optimization processes in all areas, from production, through infrastructure, to medical care" [66,101]. Regardless of the definition adopted, each IoT ecosystem is built on similar types of components. At the basic level, it is made up of the so-called system endpoints, which are sensors and actuators performing one type of function, monitoring the changes taking place (movement, temperature, humidity, location, etc.). Due to their connection capacity, they can perform two tasks, i.e., collecting and analyzing data from the environment and connecting via the Internet with control systems [102]. The next level of the Internet of Things ecosystem is created by the so-called simple hubs, i.e., joining points with a relatively small number of sensors and actuators. Due to the IT components they contain (hardware and software), embedded in specific products, they enable the optimization of their operation and adjustment of their functioning to the user's habits [67,103]. They transform them into so-called "smart products" with connectivity. They can be an integral part of a specific product or be mounted on it. Examples of the first type of solution are smart wristbands (e.g., Jawbone UP) or intelligent thermostats (e.g., Google Nest) [7,68,104]. On the other hand, the Snapshot device, which monitors the driving behavior of the car driver, is an example of the second type of solution. The third level of the Internet of Things ecosystem is the so-called integrating hubs [24,83]. They connect simple nodes, offering a wide range of similar types of services. At the same time, an appropriate infrastructure layer is necessary for the overall functioning of the Internet of Things ecosystem [105–109]. Its creation is not possible without the use of several leading technologies, which in themselves carry enormous transformational potential [110].

From the energy and sustainability point of view, it is evident that sustainable energy management cannot be attained in tourism destinations in the absence of modern technology adoption such as Internet of Things (IoT). Through application of new technological devices and applications, the robust solutions, reliable and low-cost sustainable energy sources can be developed that can enhance the performance and operation tourism destinations towards sustainable tourism development. Therefore, by using the IoT and several other communication technologies and next generation sensing applications, can be met for the demands of local communities, tourists and tourism stakeholders (see Figure 3). The IoT technology that could effectively and efficiently provide the affordable solutions for sustainable energy management is necessary to address the basic requirements of tourism destination and system. The IoT in sustainable energy management systems is envisioned as the core component of tourism growth and development in the entire tourism system, destination supply chains and tourism capital using modern technologies with the ability to fulfill the present needs of tourists and to meet needs, wants and desires of the future generation too. This paradigm of sustainable energy management with its potential to produce better experience to future generation and also useful to conversation and preservation of tourism products and resources at the global scale. The sustainable energy and IoT collectively has the tremendous potential to attain sustainable tourism development goals. Both also have the ability to minimize the negative economic, socio-cultural and environmental impacts of tourism development at the destinations. The IoT in sustainable energy management system enables various new development in tourism systems such as virtual tours especially during the time of COVID-19 pandemic, heritage walks and also help in restart and revival of tourism and hospitality industry post pandemic towards sustainable and inclusive tourism. Therefore, the present study main aim is to minimize the gap between energy management and sustainable tourism development through using the IoT as a sustainable energy management solution.

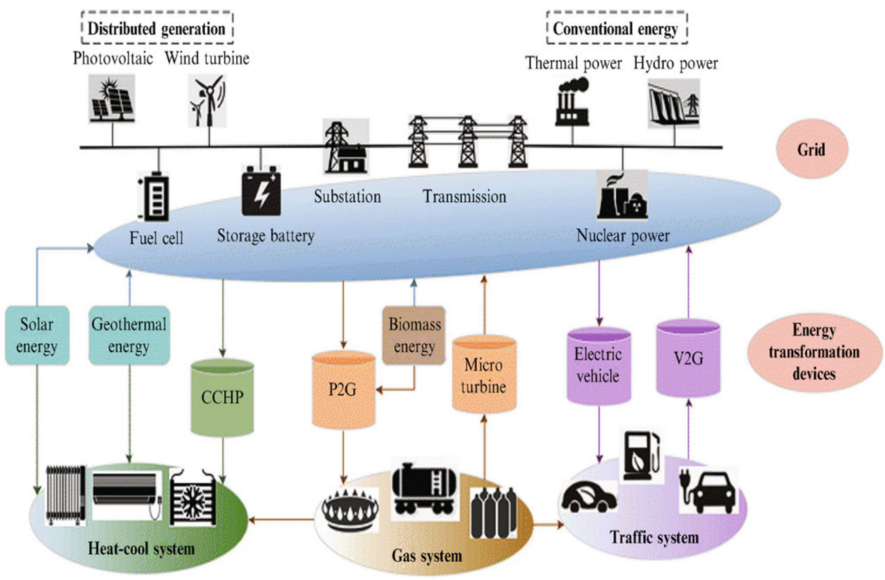

Figure 3. Sustainable Energy and IoT at Tourism Destinations (https://link.springer.com/chapter/10.1007/978-3-030-35291-2_6) (12 February 2022).

3. Materials and Methods

The present study is empirical and exploratory, conducted through normative and interview survey methods under three stages; the first phase, where selections of items, studied variables, indicators, and tools are carried out, have been carried out. Under the second stage of the pilot study, tryout one and tryout two, followed by data collection and calculation of reliability, validity, and normality of data and tool, have been conducted. Analysis of data, results, conclusions, and recommendations have been included in stage three. A sample of 300 respondents, including 100 tourists, residents, and stakeholders, has been collected from popular tourist destinations in India (majorly from UNESCO world heritage sites) by using a simple random sampling technique. After examining the demographic profiles of respondents, it was found that the highest number of respondents were private employees (129, or 43%), followed by students (84, or 28%), businessmen (51, or 17%), and government employees (36, or 12%), and the highest number of them belonged to the age group of 31–40 years (164, or 54.66%), followed by 81 (27%) between 21 and 30 years, and the rest (55, or 18.33%) were above 40 years. Out of 300 respondents, 197 (65.66%) were male, and the remaining 103 (34.33%) were female. Furthermore, the level of awareness of respondents about IoT and sustainable energy management was investigated, and we discovered that the majority of respondents (127, or 42.33%) had a low level of awareness, followed by a moderate 87 (29%), a very poor 63 (21%), and only 23 (7.66%) had a high and appropriate level of awareness and knowledge about sustainable energy and IoT.

For collecting the data, a standardized scale developed by A. Parasuraman, Valarie Zeithaml, and Leonard L. Berry by the name of SERVQUAL was used. It was used in the current study in conjunction with the Internet of Things (IoT) as an energy management solution at tourist destinations. The scale has five variables and 22 items: reliability (5), assurance (4), tangibles (4), empathy (5), and responsiveness (4). All the variables and items are related to different attributes of the IoT about sustainable energy management and are measured through expectations and perceptions of tourists, residents, and other tourism stakeholders.

Each variable and the normality of the overall scale have been examined before proceeding to data analysis, wherein reliability (indicator and internal consistency) and validity (convergent and discriminant) have been measured through Cronbach's alpha (α), rho_A (ρ), CR (composite reliability), and AVE (average variance extracted). Variable values for reliability are α = 0.830, ρ = 0.873, CR = 0.764 and AVE = 0.684, Assurance; α = 0.819, ρ = 0.705, CR = 0.863 and AVE = 0.762, Tangibles; α = 0.884, ρ = 0.874, CR = 0.794 and AVE = 0.675, Empathy; α = 0.794, ρ = 0.810, CR = 0.873 and AVE = 0.770 and Responsiveness; α = 0.883, ρ = 0.793, CR = 0.806 and AVE = 0.686. Moreover, all the values of Cronbach's alpha, rho_A, CR, and AVE were found significant and within highly acceptable ranges. Additionally, because of selecting either parametric (for normally distributed data) or non-parametric (not normally distributed data) inferential statistics, the normality of data was also checked through Skewness and Kurtosis, and their values were −0.445 and −0.321, respectively, and found within acceptable ranges of $\pm$ 2. Furthermore, expectations and perceptions of tourists, residents, and stakeholders about IoT concerning sustainable energy management were examined through a paired sample *t*-test (a parametric statistical test used to determine whether the mean difference between two sets of observations is zero or not and performed only in the case of pre and postconditions).

4. Results

The collected data (n = 300) from tourists, residents, and stakeholders over a five-point Likert scale through the SERVQUAL tool has been analyzed via a paired sample *t*-test to examine their expectations and perceptions about the Internet of Things (IoT) as a sustainable energy management solution at tourism destinations in India. However, it is the most useful concept in tourism and significantly helps destinations in making them sustainable and responsible through modern technologies such as the Internet of Things

(IoT). The results of tourists, residents, and stakeholders' expectations and perceptions are reported in Table 2.

Table 2. Paired sample *t*-test results for expectations and perceptions of tourists, residents, and tourism stakeholders towards IoT as a sustainable energy management solution at tourism destinations.

Variable	Attribute	N	Mean	S.D.	Mean Difference	t-ratio	*p*-value
Expectations and Perceptions of Tourists							
Reliability	Expectations	100	22.10	11.271	02.78	14.341	0.000 **
	Perceptions	100	19.32	07.835			
Assurance	Expectations	100	17.36	09.372	05.61	16.732	0.000 **
	Perceptions	100	11.75	0.8110			
Tangibles	Expectations	100	16.01	10.281	06.55	21.935	0.000 **
	Perceptions	100	09.46	08.381			
Empathy	Expectations	100	22.62	12.932	07.56	19.763	0.000 **
	Perceptions	100	15.06	09.372			
Responsiveness	Expectations	100	21.87	11.721	04.44	20.764	0.000 **
	Perceptions	100	17.43	09.673			
Expectations and Perceptions of Local residents							
Variable	Attribute	N	Mean	S.D.	Mean Difference	t-ratio	*p*-value
Reliability	Expectations	100	20.17	12.710	06.69	17.934	0.000 **
	Perceptions	100	13.48	08.182			
Assurance	Expectations	100	14.61	11.730	05.79	19.371	0.000 **
	Perceptions	100	08.85	03.728			
Tangibles	Expectations	100	14.87	06.739	07.14	13.670	0.000 **
	Perceptions	100	07.73	02.795			
Empathy	Expectations	100	19.46	10.854	05.92	14.673	0.000 **
	Perceptions	100	13.54	07.480			
Responsiveness	Expectations	100	18.81	09.938	05.87	12.832	0.000 **
	Perceptions	100	12.94	06.391			
Expectations and Perceptions of stakeholders							
Variable	Attribute	N	Mean	S.D.	Mean Difference	t-ratio	*p*-value
Reliability	Expectations	100	23.41	13.472	05.07	15.734	0.000 **
	Perceptions	100	18.34	09.832			
Assurance	Expectations	100	19.86	11.731	03.36	11.847	0.000 **
	Perceptions	100	16.50	09.010			
Tangibles	Expectations	100	18.45	12.832	03.48	17.930	0.000 **
	Perceptions	100	14.97	08.073			
Empathy	Expectations	100	23.60	13.931	05.43	21.040	0.000 **
	Perceptions	100	18.17	10.038			
Responsiveness	Expectations	100	24.73	14.093	05.53	18.532	0.000 **
	Perceptions	100	19.20	11.231			

** Significant at 0.01 level Primary data.

Table 2 shows the mean scores of tourists' (n = 100) expectations and perceptions about different variables of IoT about energy management solutions at tourism destinations; 22.10 and 19.32 (reliability of IoT), 17.36 and 11.75 (assurance), 16.01 and 09.46 (tangibles), 22.62 and 15.06 (empathy) and 21.87 and 17.43 responsiveness, and a mean difference of 02.78, 05.61, 06.55, 07.56, and 04.44 exist between each category, respectively. Further, values of S.D. and t-ratio are 11.271, 07.835, 09.372, 0.8110, 12.932, 09.37, 11.721, 09.673 and 14.341, 16.732, 21.935, 19.763, and 20.764 for each variable, Reliability, Assurance, Tangibles, Empathy, and Responsiveness, respectively. Additionally, the value of p is 0.000 (p = 0.000 < 0.01) for all the groups of IoT, which shows that there is a significant mean difference between expectations and perceptions of tourists about IoT as a sustainable energy management solution and with its respective attributes of reliability, assurance, tangibles, empathy, and responsiveness.

Figure 4 shows tourists had the highest expectations with empathy (individualized attention of tourists) about IoT as energy management solutions (22.62) followed by reliability (22.01), responsiveness (21.87), assurance (17.36), and tangibles (16.01), and similarly highest perceptions with reliability (19.32), responsiveness (17.43), empathy (15.06), assurance (11.75), and tangibles (09.46). Furthermore, because of overall tourist expectations and perceptions, they are most satisfied with IoT as a reliable source for sustainable energy management at tourism destinations. As with reliability, the difference between their expectations and perceptions is minimum (02.78), followed by responsiveness (04.44), assurance (05.61), tangibles (0.6.55) and empathy (07.56).

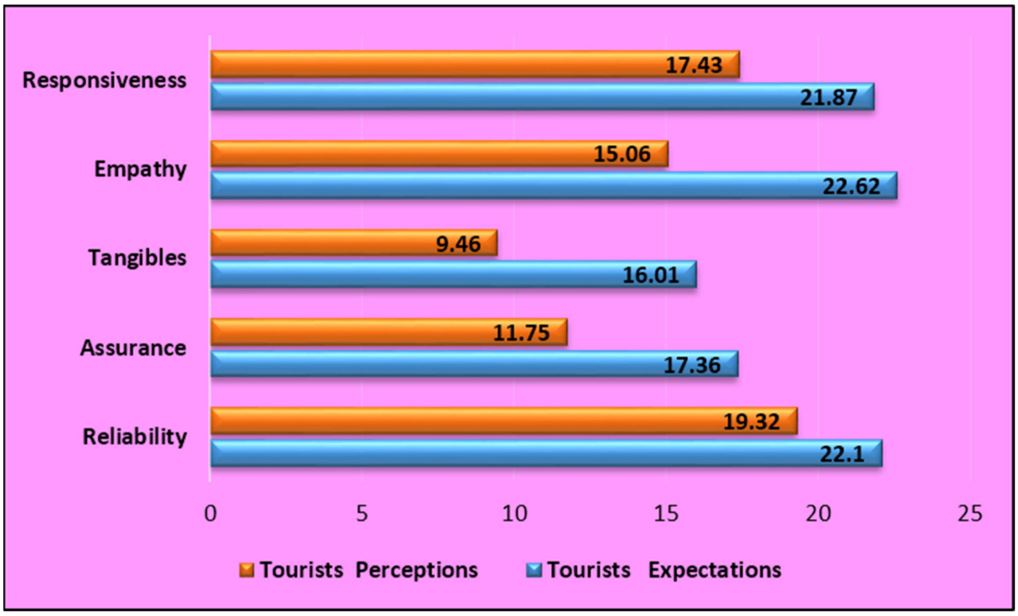

Figure 4. Expectations and perceptions of tourists about IoT as sustainable energy management solutions at tourism destinations (pictures 1–5 showing mean scores for Reliability, Assurance, Tangibles, Empathy, and Responsiveness).

In the case of residents (n = 100), their mean scores of expectations and perceptions about different variables of IoT about energy management solutions at tourism destinations are 20.17 and 13.48 (reliability of IoT), 14.61 and 08.85 (assurance), 14.87 and 07.73 (tangibles), 19.46 and 13.54 (empathy), and 18.81 and 12.94 (responsiveness), and a mean difference of 06.69, 05.79, 07.14, 05.92, and 05.87 exists between each category, respectively. Further, values of S.D. and t-ratio are 12.710, 08.182, 11.730, 03.728, 06.739, 02.795, 10.854, 07.480, 09.938, 06.391, and 17.934, 19.371, 13.670, 14.673, and 12.832 for each variable, Reliability, Assurance, Tangibles, Empathy, and Responsiveness, respectively. Additionally, the value of p is 0.000 (p = 0.000 < 0.01) for all the groups of IoT, which shows that there is a significant mean difference between expectations and perceptions of residents staying at the destinations about IoT as a sustainable energy management solution and with its respective attributes of reliability, assurance, tangibles, empathy, and responsiveness.

Figure 5 shows local residents' highest expectations with the reliability of IoT towards energy management solutions (20.17), followed by empathy (19.46), responsiveness (18.81), tangibles (14.87), and assurance (14.61), and similarly, highest perceptions with empathy (13.54), reliability (13.48), responsiveness (12.94), assurance (08.85) and tangibles (07.73). Furthermore, because of overall residents' expectations and perceptions, the most satisfied with IoT as a reliable source for sustainable energy management at tourism destinations is with assurance, because the difference between their expectations and perceptions is as low as 0.579%, followed by responsiveness (05.87), empathy (05.92), reliability (0.6.69) and tangibles (07.14).

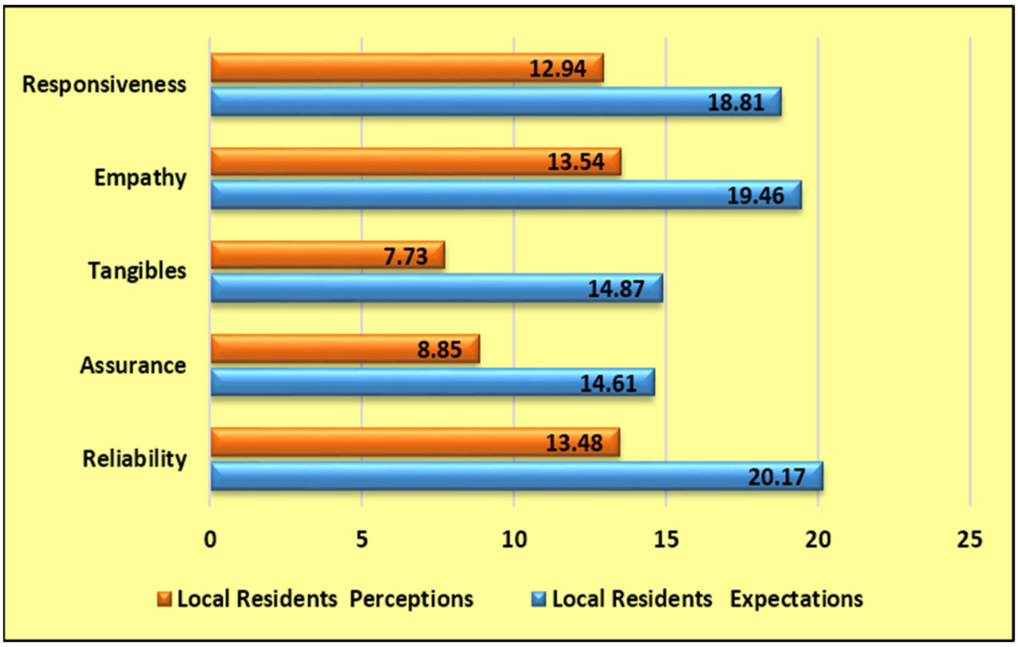

Figure 5. Expectations and perceptions of residents about IoT as a sustainable energy management solution at tourism destinations (pictures 1–5 showing means scores for Reliability, Assurance, Tangibles, Empathy, and Responsiveness).

Moreover, the sample mean scores of tourism stakeholders' (n = 100) expectations and perceptions about different variables and indicators of IoT about energy management solutions at tourism destinations are 23.41 and 18.34 (reliability of IoT), 19.86 and 16.50 (assurance), 18.45 and 14.97 (tangibles), 23.60 and 18.17 (empathy), and 24.73 and 19.20 (responsiveness), and a mean difference of 05.07, 03.36, 03.48, 05.43 and 05.53 exists between each category respectively. Further, values of S.D. and t-ratio are 13.472, 09.832, 11.731, 09.010, 12.832, 08.073, 13.931, 10.038, 14.093, 11.231 and 15.734, 11.847, 17.930, 21.040, and 18.532 for each variable, Reliability, Assurance, Tangibles, Empathy, and Responsiveness, respectively. Additionally, the value of p is 0.000 (p = 0.000 < 0.01) for all the groups of IoT, which shows that there is a significant mean difference between expectations and perceptions of tourism stakeholders about IoT as a sustainable energy management solution and with its respective attributes of reliability, assurance, tangibles, empathy, and responsiveness.

Figure 6 shows stakeholders had the highest expectations for the responsiveness of IoT about energy management solutions (24.20), followed by empathy (23.60), reliability (23.41), assurance (19.86), and tangibles (18.45), and similarly highest perceptions for assurance (19.86), responsiveness (19.20), reliability (18.34), empathy (18.17) and tangibles (04.97). Furthermore, because of overall tourism stakeholders' expectations and perceptions, they are most satisfied with IoT as a trustworthy (assurance) source for sustainable energy management at tourism destinations. As with assurance, the difference between their expectations and perceptions is the minimum (3.36), followed by tangibles (3.48), reliability (05.07), empathy (0.5.43), and responsiveness (07.56).

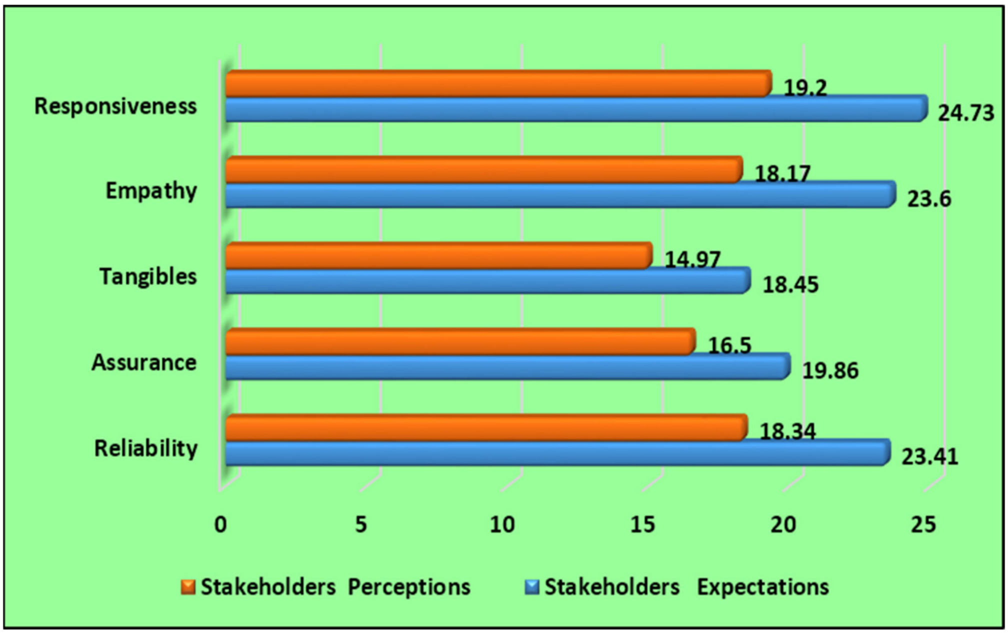

Figure 6. Expectations and perceptions of tourism stakeholders about IoT as a sustainable energy management solution at tourism destinations (pictures 1–5 showing mean scores for Reliability, Assurance, Tangibles, Empathy, and Responsiveness).

After understanding the various aspects of the Internet of Things (IoT) in relation to sustainable energy management and measuring the expectations and perceptions of tourists, local residents and stakeholders, where we wound, reliability, assurance, tangibles, empathy and responsiveness of IoT as sustainable energy management solutions at tourism destinations in India, tourism stakeholders have higher level of expectations (23.41, 19.86, 18.45, 23.60 and 24.73) and perceptions (18.34, 16.50, 14.97, 18.17 and 19.20) followed by tourists expectations (22.10, 17.36, 16.01, 22.62 and 21.87) and perceptions (19.32, 11.75, 09.46, 15.06 and 17.43) and local residents expectations (20.17, 14.61, 14.87, 19.46 and 18.81) and perceptions (13.48, 08.85, 07.73, 13.54 and 12.94), respectively. That means, compared with tourists and local residents, tourism stakeholders are more knowledgeable and aware about uses of IoT as sustainable energy management solution in tourism destinations in India. However, they all (tourists, local communities and stakeholders) felt the importance of IoT as sustainable energy management solution and shown strong intentions to use and integrate various IoT devices and applications for revival and rejuvenation of tourism destinations in India toward responsible destination and sustainable tourism development. Moreover, countries such as India where local residents are not as aware about modern innovations in tourism and sustainable energy management solutions such as the Internet of Things (IoT), but they are very much interested to know and make them implement for the betterment of destination, products and services. Similarly, tourists and tourism stakeholders are also expecting good results of IoT and its applications for sustainable tourism management and positive perception and satisfaction to tourists, local residents and stakeholders (See it in Figure 7).

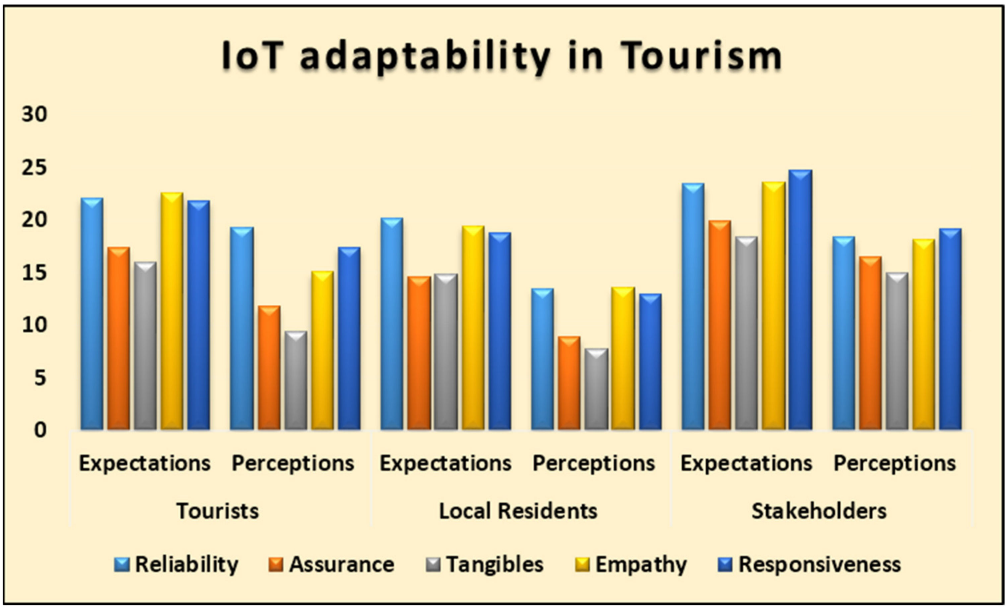

Figure 7. IoT adaptability in Tourism.

5. Conclusions and Recommendations

To examine the awareness and acceptance of the Internet of Things (IoT) by tourism destinations, which majorly constitute the tourism system, about planning and management of sustainable energy (energy and natural resources at destinations meeting the needs of future generations even without compromising present needs, wants, and desires of tourism personnel), expectations and perception of tourists, residents, and stakeholders were measured critically and empirically. Tourists, residents, and tourism stakeholders are the moral and legal stakeholders in the tourism sector who determine and conduct the entire tourism system at all levels, and tourism cannot develop with their active participation. Therefore, expectations and perceptions of tourists [111], residents [112], and stakeholders [113] are very crucial to investigating any new concept, trend, or innovation in tourism, before and after their applications. The same has been examined in this particular study regarding the IoT and its technologies [114].

Results of the study suggested that all in all, tourists, residents, and stakeholders wanted to manage and overcome environmental issues such as ecological imbalances, loss of fauna and flora, emission of greenhouse gases, energy poverty, radioactive waste, nuclear proliferation, climate change, pollution (air, noise, and water), over-tourism, and global warming, etc., at tourism destinations due to unsustainable tourism practices followed by them. The IoT is most hopeful and positive for them as a sustainable energy management solution for these issues. After the analysis, it has been found that stakeholders have high positive expectations and perceptions followed by tourists and residents towards the Internet of Things (IoT) and its latent variables and indicators: reliability, assurance, tangibles, empathy, and responsiveness, as they have a different level of awareness and understanding about IoT technologies and tourism.

The present study concluded and proven that IoT has become the most needed and powerful tool for the tourism industry for planning, promotion, managing, and sustainable development, therefore it is recommended to tourism planners, policies makers, destination management organizations, companies, tourism boards, hoteliers, transporters, tourists, residents and other direct or indirect associated tourism stakeholders with tourism and hospitality industry, that they all must understand, educate, focus and move towards Internet of Things (IoT) technologies while managing and conducting the entire tourism system, resources (natural and man-made), products, services and operations in responsible and sustainable ways. Additionally, findings suggested that IoT is most reliable, responsive, trustworthy, people-friendly, and productive for tourism destinations in all stages: identification, exploration, development, consolidation and stagnation, and rejuvenation (helping destinations not to face decline stage). IoT technologies such as artificial intelligence (AR), virtual reality (VR), Virtual Assistants and chatbots, etc. are significantly helping in machine learning, providing automated, customized, and cost-effective travel experiences to tourists according to their needs, wants, and desires and also facilitating customization, profiling of tourism destinations, resources and products, smooth travel, maintenance and repairing, parking information, smart energy-saving and many more. Over the period, due to modernization, privatization, and globalization needs, wants, and desires of tourists have been changing with greater pace, hence it has become most important to modify the tourism products and services according to them via using modern technologies and applications such as IoT, to survive, revive and transform the tourism sector. The present study is one of the novels and sustainable approach towards it.

Results of the present study shows that without integrating IoT with tourism destinations not only in India and but also in any destination across the globe, tourism cannot be develop in responsibly and sustainably. As IoT systems and databases are very useful and necessary for sustainable energy and destination management such as: (1) Solar Roadmap; a destination level solar information database help to increase adoption of solar energy by tourism stakeholders and local residents, (2) Bioenergy Atlas; an integrated mapping system for the local vendors using biofuels and bio power for their businesses and operations, (3) RET Screen; a clean energy software, quite useful for maintaining ecological balance over tourism destinations, (4) Planning Framework for a Climate-Resilient Economy; a destination level framework for climate resiliency towards climate changes and biodiversity and identification of economic vulnerability at popular tourism destinations, (5) Geothermal Prospector; a technique to map and profile the geothermal power of natural tourism resources and products, (6) US Energy Information Administration (EIA); a US based energy mapping system, help in development of energy infrastructure databases within tourism systems, (7) Bioenergy Knowledge Discovery Framework (KDF); very useful database for bioenergy analysis at natural tourism destinations, research and development, and planning and development of sustainable tourism, (8) Hydro source; it is an integrated and comprehensive data set for maintaining water, energy, and ecosystem sustainability in tourism destinations. It also has geospatial data sets for water management and hydro-electricity production, which is one of the core indicators of sustainability and (9) U.S. Electric System Operating Data; a tool for analyzing and visualizing the hourly demand of electricity at tourism destinations. Further, IoT has varieties of applications and approaches such as distributed monitoring approach, multi-agent anomaly detection, distributed clustering approach and Intrusion Detection Systems (IDS) etc. and help in operating tourism destinations independently via centralized server [115], improving the transportation system at tourism destinations, minimizing the energy consumption and traffic congestion [116] and providing conventional and virtual tours to tourists [117]. Furthermore, towards the sustainable development of transportation system which is one of the important components of sustainable tourism development over tourism destination, operation of electric vehicle, charging stations and smart grid integration applications play a significant role in sustainable and green energy management [118]. Now, it has been quite clear that every tourism destination must go towards the Internet of Things (IoT) to restart, revive and rejuvenate themselves according to the present needs. IoT is also regarded as a complete and comprehensive tool for sustainable energy and tourism management in both natural and cultural tourism destinations in India and the World.

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