HOSPITALITY INDUSTRY 4.0 AND CLIMATE CHANGE

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ADEL BEN YOUSSEF
ADELINA ZEQIRI

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Hospitality Industry 4.0 and Climate Change

Adel Ben Youssef
Université Côte d’Azur, CNRS, GREDEG, France
5, rue du 22e BCA, 06357 Nice cedex 4
E-mail: adel.ben-youssef@gredeg.cnrs.fr

Adelina Zeqiri
Faculty of Economics, University of Prishtina “Hasan Prishtina”
Str. Agim Ramadani, n.n., 10000 Prishtina, Kosovo
E-mail: adelina.zeqiri@uni-pr.edu

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Abstract

This paper investigates the main principles supporting hospitality industry 4.0, the effects of hospitality industry activities on climate change, and the ways that hospitality industry 4.0 might contribute to combating climate change. In the context of the focus of contemporary industries on sustainable development, the fourth industrial revolution or industry 4.0 can be considered an enabler of sustainability. Among those industries considered to be major contributors to climate change is the hospitality industry which has increased research interest in this sector. The hospitality industry includes the travel and tourism, accommodation and food and beverages sectors all of which are contributing in different ways to greenhouse gas (GHG) emissions. The introduction of industry 4.0 technologies could help hospitality industry to reduce its effects on climate change through increased energy efficiency, recycling and re-use of water, and reduced food waste. The notion of circular hospitality involving reuse, recycling, redesign, replacement and rethinking strategies, and use of virtual reality to reduce transport and travel are enabled by industry 4.0 technologies. Hospitality industry 4.0 technologies offer new opportunities for enhancing sustainable development and reducing GHG emissions through the use of environmentally friendly approaches, to achieve the Paris agreement objectives.

Key words: Hospitality, Hospitality Industry 4.0, Climate Change, Circular Hospitality, Sustainability, Energy Efficiency

JEL Codes: Q54, L83, O33
Introduction

The aim of this paper is to investigate how implementation of industry 4.0 in the hospitality sector could help to combat climate change. Previous work has studied some of the impacts of industry 4.0 in this sector but not its effects on climate change, or the different effects of the hospitality industry on climate change in the absence of industry 4.0.

There is a strand of work on the potential effects of climate change on tourism and the contribution of tourism to climate change (Dubois et al., 2016; Gössling and Hall, 2006; Odimegwu and Francis, 2018; Peeters and Dubois, 2010; Scott et al., 2012). Climate change is considered one of the most serious problems faced by humanity today (Contreras and Platania, 2019). The Intergovernmental Panel on Climate Change (IPCC) (2013) studied global warming since the late 19th century and provides evidence of changes related to atmospheric and ocean warming, diminishing snow and ice amounts, rising sea levels, and increasing greenhouse gas (GHG) concentrations. In the absence of urgent actions, these effects can be expected to be worsen (IPCC, 2018). Since travel and tourism are highly climate sensitive, this sector is considered one of the main contributors to GHG emissions (Gössling, 2013). Tourism accounts for 5% of global carbon emissions and among the total emissions generated by tourism 75% are due to transport, 21% to accommodation and 4% to other tourism activities (UNWTO et al., 2008). Tourism is expected to grow at an average rate of 3.3% per year between 2010-2030, reaching 1.8 billion international tourist arrivals in 2030 (UNTWO, 2017) which due to the accompanying increased carbon emissions and environmental pollution will have a major impact on climate change (Ben Jebli and
Hadhri, 2018). The projected increase in international tourist arrivals worldwide means that changes to the tourism sector could contribute greatly to the achievement of the United Nations Sustainable Development Goals (UNSDG) and could be important for delivering sustainable solutions for human and environmental wellbeing.

At the same time, there is stream of work examining the links between the hospitality industry and the various pillars of industry 4.0 such as the Internet of things (IoT) (Car et al., 2019; Kansakar et al., 2019; Nadkarni et al., 2019; Verma and Shukla, 2019), virtual reality (VR) (Guttentag, 2010; Huang et al., 2016; Ja Kim et al., 2020; Kim and Hall, 2019; Nayyar et al., 2018; Wiltshier and Clarke, 2016), augmented reality (AR) (Jung and tom Dieck, 2017; Kounavis et al., 2012; Nayyar et al., 2018), big data (Li et al., 2018; Nadkarni et al., 2019), artificial intelligence (AI) and robotics (Ivanov et al., 2017; Kuo et al., 2017). Most of this work discusses the reshaping of the hospitality industry as the result of implementing industry 4.0 technologies, aimed at providing personalized experiences and digitalization of the services.

Work on the direct links of industry 4.0 as an enabler of sustainability in the hospitality sector is nascent (Eskerod et al., 2019; Parida et al., 2019). Eskerod et al. (2019) examine the drivers influencing the adoption by hotels of IoT technology to pursue sustainability, and Parida et al. (2019) explore the links between digitalization, business model innovation, and sustainability. To our knowledge, there are no investigations of the potential role of hospitality industry 4.0 to combat climate change.

The present paper provides three contributions to try to fill the gaps in the literature. First, it examines the role and main pillars of industry 4.0 in the hospitality industry, and how it is

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1 These figures need to be updated given the recent outbreak of COVID-19 and its potential impacts.
reshaping the sector. We consider cyber physical systems (CPS), the IoT, VR, AR, big data, and AI and robotics. Second, we explore the relationship between the hospitality industry and climate change by discussing the effects of climate change on tourism and the contribution of tourism to climate change. We consider adaptation and mitigation strategies to fight climate change. Third, we examine sustainable solutions to environmental change in different sectors of the hospitality industry. We propose five ways that implementation of industry 4.0 technologies in hospitality could help to mitigate climate change. Hospitality industry 4.0 enables first, increased energy efficiency, second, increased water use efficiency, third, reduced food waste, fourth, “circular hospitality”, and fifth, replacement of transport and travel by virtual reality. Several technological issues would be resolved through implementation of industry 4.0 which would result in more sustainable business performance (Haseeb et al., 2019).

The paper is organized as follows: section 1 discusses the concept of hospitality industry 4.0 and its underpinnings, section 2 examines the relationship between climate change and tourism, section 3 shows how hospitality industry 4.0 could contribute to reducing climate change, and section 4 offers some conclusions and policy implications.

**Section 1. What is hospitality industry 4.0?**

Rapid technological development and the increased pace of innovation have caused paradigm shifts or industrial revolutions (Lasi et al., 2014). The most recent is the 4\textsuperscript{th} industrial revolution. Similar to previous industrial revolutions, industry 4.0 is characterized by its effects on industry. The first industrial revolution involved mechanization and the introduction of steam and water power; the second industrial revolution saw the introduction of mass production and assembly
lines based on electrical power; the third industrial revolution involved automation of production and computers. The fourth industrial revolution is characterized by CPS and the interconnection between the virtual and physical worlds. Frank et al. (2019, p. 343) define industry 4.0 “as a new industrial maturity stage of product firms, based on the connectivity provided by the industrial Internet of things, where the companies' products and process are interconnected and integrated to achieve higher value for both customers and the companies' internal processes.”

Industry 4.0 is affecting the hospitality industry. The aim of so-called hospitality industry 4.0 is to create more personalized and digitalized services for consumers. It should solve problems related to massification, individual experience, and sustainability. Smart hospitality is envisaged as an interoperable and interconnected system enabling information sharing which will provide added value for the entire ecosystem of stakeholders via digital platforms (Buhalis and Amaranggana, 2015; Buhalis and Leung, 2018). Smart hospitality will allow exchanges of information along the value chain, and will put customers at the center of the process through personalized and contextualized services and experiences (Buhalis and Leung, 2018). The use of new technologies has change the behavior of consumers regarding to the use of hospitality services (Zeqiri et al., 2020a) Consumers will be embedded in a digital environment that will allow them to engage in various activities using digital technologies. Consumers are no longer satisfied by the provision of only essential facilities and hospitality must change to satisfy their expectations.

1.1. **Hospitality industry 4.0 technologies**

The fourth industrial revolution includes a set of technological developments such as CPS, the IoT, AR, VR, AI and robotics, big data, blockchain, and 3D printing (Bilgin Sari, 2018; Pereira and
We argue that CPS, IoT, AR, VR, AI and robotics, and big data are the aspects of industry 4.0 that will affect the hospitality industry. The interconnection of the technologies of Industry 4.0 can be achieved through the use of horizontal, vertical and end-to-end system integration tools along the value chain (Ben Youssef, 2020).

**CPS** are a main pillar of industry 4.0. They are defined as integrated and interconnected physical and virtual arrangements based on computation, communication, and control systems (Lee et al., 2015). Sensors, 3D scanners, cameras, and radio frequency identification (RFID) devices are used by CPS to collect data (Nagy et al., 2018). Embedded CPS enable the exchange of data in smart networks (Pereira and Romero, 2017). The IoT is based on the interconnection of CPS with the Internet (Jazdi, 2014). According to Lee et al. (2015), CPS comprise two aspects: first, interconnection of the physical and cyber worlds which enables access to the real-time data; second, smart data management, analytics and computational capability. CPS allow autonomous and decentralized production processes (Vaidya et al., 2018).

The **IoT** is another important pillar of industry 4.0. It involves interconnectivity among physical devices such as sensors, actuators, RFID tags, laptops, and mobile phones, and their communication through networks or the Internet which enable integration of the physical and cyber worlds (Munir et al., 2017). RFID enable the identification of objects or humans; wireless sensor networks can sense the environment and process data through large numbers of nodes which enable communication and computation; smart technology can transform objects into smart objects able to communicate with users in active or passive ways; and nanotechnology allows interconnection of nanoscale objects (Yun and Yuxin, 2010). The IoT includes smart vehicles and smart homes to enable integration of services such as notifications, security, energy saving, automation, communication, computing, and entertainment (Saranya and Nitha, 2015).
context of the hospitality industry, the emergence of IoT technology is transforming hotels into smart hotels within smart cities (Mohanty et al., 2016). Application of the IoT in the hospitality sector allows interactions with tourists, and collection of real time tourist data. It allows instant, personalized and localized services, and accurate evaluation of tourists’ behaviors and preferences (Kansakar et al., 2019).

Another pillar of industry 4.0 which is affecting the hospitality industry is AR which involves the combination of real and virtual objects in a real environment, synchronization of real and virtual objects, and interaction in 3D and real time (van Krevelen and Poelman, 2010). There are several types of AR technologies (Nayyar et al., 2018): Marker-based AR enables the scanning of physical images through a camera and visual markers which can be sensed by readers; Markerless AR or GPS-based AR provide data on precise location; Projection-based AR allows projection of artificial light on the surface of the real world; and Superimposition-based AR enables partial or complete replacement of the original object view by an augmented view. In recent years, AR has provided opportunities for hospitality businesses and tourists. It provides tourists with more personalized services and additional benefits such as navigation of selected locations and allow tourists to share and exchange information and opinions with other tourists in large networks (Kounavis et al., 2012).

While AR augments elements in the real environment, VR simulates reality (Tussyadiah et al., 2018). According to Desai et al. (2014, p. 175) VR is “a computer simulated (3D) environment that gives the user the experience of being present in that environment”. It provides people with opportunities for virtual travel (Mura et al., 2017). It contributes to sustainable tourism by providing the opportunity for low cost and environmentally friendly travel (Wiltshier and Clarke, 2016). VR allows people to visit difficult to access places, to travel across time, and to enter
fantasy worlds (Cheong, 1995) and allows people of all ages and those with reduced mobility to enjoy tourism and participate in online communities (Wiltshier and Clarke, 2016).

**Big data analytics** are related to recent technological developments which have increased the amounts of data generated making traditional techniques insufficient to cope with their processing and analysis. The hospitality industry captures and generates huge volumes of data on consumer preferences and characteristics. In the hospitality sector, big data include internal big data which are held in central databases, and external big data which are collected from the Internet via sensors. Data can be classified based on their characteristics and type, and hospitality ecosystem actors can access and use these data to prepare strategic business plans and manage their operations in a dynamic way (Buhalis and Leung, 2018). The hospitality industry needs to understand tourist preferences, behaviors, and locations in order to offer personalized services. This involves the collection, storage, and use of data in appropriate ways and their protection from threats. Computing resources help to enhance the security and interconnectivity of tourist networks with the hospitality industry (Kansakar et al., 2019). However, secure data storage is a major problem.

**AI and robots** are used in the hospitality sector to create more personalized and unique experiences at low cost. Service robots in workplaces maintain contact with people in a shared non-industrial environment (Tung and Law, 2017). Robots can replace humans in R&D activities (Horváth and Szabó, 2019). Robots are being used by airport managements to substitute for traveler information centers, and allow services that do not require human interaction. Hotels use robots to support both their employees and their consumers (Ivanov et al., 2017). Continued development of advanced technology will make AI and intelligent robots more affordable and faster and more reliable than humans.
Section 2. Tourism and climate change: twofold relationship

The relationship between climate change and tourism has been the topic of debate for many years. The first international climate change conference in the context of tourism was held in 2003 in Djerba, Tunisia (World Tourism Organization, 2003) when the importance of the tourism industry to the global economy and its vulnerability to the impacts of climate change were emphasized. It was agreed that there was a need to develop sustainable policies and reduce GHG emissions (World Tourism Organization, 2003). In 2007, the second International Conference on Climate Change and Tourism was held in Davos, Switzerland, and discussion on climate change and tourism continued in the framework of the United Nations Environment Programme, the World Meteorological Organization, and the United Nations Framework Convention on Climate Change (UNFCCC), at the UN Climate Change summit in Bali. The conference theme “Tourism: responding to the challenge of climate change” was the centerpiece of the 2008 World Tourism Day (UNWTO et al., 2008). UNWTO et al. (2008, p. 13) states that “climate is a key resource for tourism and the sector is highly sensitive to the impacts of climate change and global warming, many elements of which are already being felt.” Debate on the importance of climate change was reignited by the definition of the UNSDG. SDG 13 was aimed at combating climate change (United Nations, 2015) and led to the Paris Agreement on Climate Change (UNFCCC, 2015). In 2018, the World Travel and Tourism Council (WTTC) and the UNFCCC agreed a common agenda for climate action related to travel and tourism to tackle climate change.
Figure 1. Two-way relationship between tourism and climate change

Source: Patterson, Bastianoni and Simpson (2006)

Debate on the relationship between tourism and climate change (Hoogendoorn and Fitchett, 2016) and is complexity (Dubois et al., 2016) has continued: tourism affects climate change and climate change affects tourism (Odimegwu and Francis, 2018). On the one hand, tourism and its associated activities contribute to climate change (Nicholls, 2006). Tourism contributes to GHG emissions through transport, accommodation (Scott et al., 2010), food production and consumption (Sinclair-Maragh, 2016), and other activities. In the case of transport, the largest contributor to carbon emissions is air travel, followed by car transport (Scott et al., 2010). On the other hand, tourism is affected by climate change in the form of heat waves and rising sea levels. Other impacts include changes to arctic temperatures and ice, precipitation amounts, ocean salinity, and wind patterns, and more frequent occurrence of extreme weather events such as droughts and tropical cyclones (IPCC, 2007). These aspects affect coastlines, cause erosion on beaches, water shortages, forest fires, desertification, extinction of wild life and damage to heritage sites (Sinclair-Maragh, 2016). Further, Hall et al. (2015, p. 2) suggest that climate change “is extremely significant for tourism
because of its influences on the economic viability of tourism destinations and activities, tourist behavior, and its ramifications for the entire tourism system”. According to IPCC (2018), tourism is already being affected by global warming, with increased risks of an additional 1.5°C of warming in specific geographic regions which will affect beach and snow sports destinations. The link between tourism and climate is important for people planning holidays and other leisure travel. According to Zanni et al. (2017), considerable numbers of people changed their travel plans due to the weather related disruption. The weather affects destination choices and tourist satisfaction (Coghlan and Prideaux, 2009).

**2.1. Adaptation and mitigation strategies**

There are two important climate change strategies in the tourism industry: adaptation and mitigation (Patterson et al., 2006; UNWTO et al., 2008). According to the findings of the IPCC Fifth Assessment Report (AR5), summarized by Scott, Hall, and Gössling (2016, p. 15), it is suggested that “all tourism destinations will need to adapt to climate change, whether to minimize risks or to capitalize on new opportunities”. Adaptation involves means to moderate or curb the impact of climate change by institutions, governments, individuals, and corporations (Odimegwu and Francis, 2018). Adaptation efforts in the tourism sector differ across sectors, activities, and destinations. They include protection for coastlines and provision of artificial snow to allow continued tourism to ski resorts experiencing less snowfall during the ski season (Dawson and Scott, 2013; Scott et al., 2012). The strategies employed depend on different social, economic, and environmental conditions (Dogru et al., 2019).

Climate change mitigation includes efforts to reduce the effects of tourism (Odimegwu and Francis, 2018) which can be achieved via use of industry 4.0 technologies. Below, we discuss in
more detail five ways that industry 4.0 technologies could allow the hospitality industry to reduce its carbon footprint.

Section 3. How hospitality industry 4.0 could help to combat climate change

Ben Youssef (2020) has proposed four ways that industry 4.0 can help combatting climate change: promoting energy efficiency and achieve substantial energy gains; enable the circular economy; achieve sustainable development through eco-innovation; allow significant technology transfer to the Least Developed Countries (LDCs). The application of industry 4.0 to combat climate change requires three main issues to be taken into consideration (Ben Youssef, 2020): first, cloud computing providers need to shift to renewable energies and less use of fossil fuel energy; second, before massive adoption of industry 4.0, economic and societal transformation needs to be taken into consideration; third, industry 4.0 needs important governance and there is a need to agree regarding to the ethical considerations.

Energy, water, and food waste are major issues especially for hotels. In this regard, we propose five ways that hospitality industry 4.0 could help to combat climate change: use of technologies of industry 4.0 could increase energy and water use efficiency, and reduce food waste, allow circular hospitality, and minimize transport and travel.

3.1. Using less energy (increased energy efficiency)

Several studies (Ahmad et al., 2016; Costa et al., 2013; Shaikh et al., 2014) show that buildings consume 40% of the world’s energy which accounts for 30% of CO2 emissions. There should be an emphasis on green incentives, green programs, and modern heating, cooling, and water systems
using digital technologies to record and report green efforts and use energy more efficiently to reduce CO2 emissions. On average, some 30% of energy savings could be achieved through the implementation of intelligent automation technologies in buildings (Shaikh et al., 2014). According to Harish and Kumar (2016), new buildings could achieve energy savings of between 20% and 50% through the incorporation of appropriate building, heating, ventilation, and air-conditioning (HVAC, 20%–60%), lighting (20%–50%), water heating (20%–70%), refrigeration (20%–70%), and electronics and other designs (10%–20%).

Sustainability can be considered as one among challenges that is facing hospitality industry (Zeqiri et al. 2020b). Sustainable tourism is a top priority for all tourist venues and there needs to be a reassessment of hospitality companies' environmental priorities to ensure more sustainable operations. New technologies could provide hotel staff with critical data and alerts to help them to manage energy consumption and support sustainability initiatives. The IoT could contribute to more efficient energy use in the hospitality sector. On the one hand, the hospitality industry is trying to offer more personalized services and provide unique experiences for consumers. The IoT enables data exchange via access points and sensors which allows hotels to provide personalized services to guests. IoT-enabled devices in hotel rooms allow guests to transform general spaces into personalized domains or smart rooms (Eskerod et al., 2019). On the other hand, the hospitality industry is trying to respond to travelers’ desire to travel more sustainably; a sustainable travel report conducted by Booking.com (2018) found that 87% of global travelers wanted to travel sustainably.

In addition to personalized consumer services, the IoT will allow more efficient energy use based on smart devices and energy-saving systems. According to Eskerod et al. (2019) the use of smart energy management systems could reduce hotel energy costs by 20% to 25%. Many hotels are
employing smart lightning, temperature control equipment, and devices such as compact florescent bulbs and LED lights allowing low power generation (Kansakar et al., 2019). The use of heating and cooling technologies depends on the temperatures; higher temperatures increase use of air conditioners and call for more efficient air conditioning technologies (Auffhammer et al., 2017). Smart HVAC systems use occupancy sensors and machine learning algorithms to continuously analyze demand and load patterns and optimize HVAC energy consumption, while smart lighting systems allow hotels to set lighting times based on occupation patterns, and improve overall lighting energy consumption throughout the year. The use of sensors to monitor HVAC systems saves time and reduces maintenance requirements. A control center provides information related to lighting including energy consumption per fixture when lights are off or are on for longer than considered necessary (Eskerod et al., 2019). For example, guests often adjust temperature thermostats and forget to turn off TVs and lights. New technologies adjust room temperature and turn off lights and TVs automatically when guests leave their rooms.

As industry 4.0 technologies become more ubiquitous, they are being used in more and more places for different purposes. The IoT can transform homes into smart homes. Smart thermostats, compact florescent bulbs and LED lights, smart door locks, etc. can be used by all household members. People looking for accommodation are demanding at least the same level of technology as in their own homes. In addition, hospitality companies need to adopt new technologies to become more sustainable, increase energy efficiency, and reduce CO2 emissions.

3.2. Reducing water consumption increasing water use efficiency
Water consumption is a major item in the hotel and accommodation sector and contributes significantly to carbon emissions. According to UNWTO (2020), the number of international tourist arrivals worldwide increased 4% in 2019 to 1.5 billion and this growth in international tourist arrivals is increasing the tourism carbon footprint (Lenzen et al., 2018) and affecting water resources. It is estimated that water consumption ranges between 84 liters and 2000 liters per tourist per day, or up to 3423 liters per room per day (Gössling et al., 2012). According to De Freitas et al. (2017) showering is the biggest consumer of water; in apartments, hotels and houses around 25% of total water consumed per month is due to showering. During the winter, when temperatures are low, there is a dramatic increase in hot water consumption (De Freitas Melo et al., 2017). In addition to being the main source of water consumption in tourism accommodation (Gössling et al., 2012), showering and bathing are energy-intensive and increase carbon emissions (Tiefenbeck et al., 2018).

Smart buildings use various technologies to achieve sustainable development and more efficient use of resources. Hotels are implementing innovative water-saving devices which allow the collection and use of rainwater, separation of “grey” water for composting toilets, and water recycling. Also, hotel guests should be encouraged to reuse towels, and showers should be installed to replace baths (Walmsley, 2011). The IoT has provided new perspectives on smart buildings and efficient use of resources (De Freitas Melo et al., 2017). IoT-enabled water meters can be used to monitor water use at low cost. Use of smart bathrooms equipped with smart showers, smart sinks, flow-controlled toilets, etc. help to reduce water consumption in hotels (Kansakar et al., 2019).

Prasad et al. (2016) propose a smart water quality monitoring system using IoT and remote sensing technology. Technologies allow the sending of alerts about the action that should be taken to ensure water quality, and provide real time water monitoring. Saseendran and Nithya (2016) describe an
automated water usage monitoring system which uses the IoT to control water use and waste at home or in industry via wireless sensor nodes. The data are collected through Wi-Fi/LAN to monitor and track water use and waste. Users received notifications on mobile phones on water use or if projected water use is exceeded. Users can control water use using a mobile phone or a laptop connected to the Internet. Ahemed and Amjad (2019) discuss a water management system (WMS) able to control and monitor water use in various spaces such as hotels, houses, irrigated land, and industry. The WMS monitors the water storage tank and takes action if the water level becomes too high or too low. Users can change the temperature of the water.

Pereira et al. (2019) describe a smart technology solution called Aguardio, which collects data on guests’ shower durations and showering behavior. Aguardio was developed by a Danish company specifically for the hospitality industry. Machine learning algorithms are used to identify showering behavior via an IBM Watson AI platform. Sensors send information on shower duration and nudge the user to reduce it. Pereira et al. (2019) studies a hotel in Spain with Aguardio installed in 20 individual rooms. The findings indicate that real-time feedback nudges reduced guest shower times by 12.06% on average, or 40.91 seconds and 6.14 liters of water.

3.3. Reduction of food waste

Food waste is an issue for all countries worldwide. It is estimated that 1.3 billion tonnes of food is wasted annually (FAO, 2013) and that waste food is responsible for about 8% of global GHG emissions (FAO, 2015).
Food waste is especially critical issue for the hospitality industry. How much food is wasted is debatable (Goh and Jie, 2019). In the UK, it is estimated that, annually, 920,000 tonnes of food is wasted at outlets, 75% of which was avoidable and was edible (WRAP, 2013). In Sri Lanka it is estimated that 79% of total hotel waste is food waste (International Finance Corporation, 2013). Large amounts of food are wasted every day and much of it could be used to feed the world’s hungry people. Action is needed to reduce and prevent food waste. Attention to the issue of food waste prevention has grown in light of the UNSDGs. SDG 2 and SDG 12 are aimed respectively at ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture by 2030, and halving per capita global food waste at the retail and consumer levels, reducing food losses in production and supply chains including post-harvest losses, and substantially reducing waste generation through prevention, reduction, recycling and reuse by 2030 (United Nations, 2015).

Recent digital innovations can help reduce food waste in the hospitality sector by allowing more accurate forecasting of demand and supply. AI and big data can help to reduce food waste from kitchens, and smart phone and other apps are available. “Wise Up on Waste” was developed by Unilever Food Solutions to allow kitchen professionals to measure, monitor and manage food waste and reduce costs. “Karma” is another app which helps restaurants and cafes to reduce food waste by enabling them to sell what would otherwise be unsold food, at reduced prices. Consumers can order via the app and buy the food as a takeaway item. This reduces food waste in restaurants and allows consumers to buy food at reduced prices. Winnow Solutions has developed a smart

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3 See: [https://karma.life/](https://karma.life/)
4 See: [https://www.winnowsolutions.com/](https://www.winnowsolutions.com/)
tool involving a touchscreen which allows staff to identify what is being thrown away and when. The AI device sends notifications about the cost of the food being thrown away and records daily waste. This kind of information is helping chefs in hotels, restaurants, etc. to manage their food use and reduce food waste and is providing information on consumer preferences. It allows new menus to be devised based on daily food waste. Food waste includes the water, energy, and other resources used in its preparation; therefore, reducing food waste reduces both cost and environmental footprint.

Wen et al. (2018) discuss an IoT-based food waste management system for restaurants that was developed and is being implemented in Suzhou, China. It consists of an RFID system and a sensor system which provide real-time data on food waste to the catering companies involved; a smart food waste collection truck equipped with RFID readers, weight sensors, GPS, geographic information system (GIS), and wireless video surveillance cameras to enable real-time supervision of collection and transportation of food waste; sensors which monitor biodiesel, biogas, and organic fertilizer production at disposal facilities in real time; and an online management system which enables real-time data visualization, statistics, queries, analytic processing, local surveillance, and information on processing bottlenecks. Implementation of the system has had positive effects and resulted in better management of food waste across the value chain. Hong et al. (2014) proposed an IoT-based smart garbage system (SGS) which collects and analyzes information on food waste. The system was implemented as a one-year pilot project in Seoul’s Gangnam district, and the results show average amount food waste reductions of 33%.

AI and big data allow food quality to be monitored to identify food that can be consumed and food that should be thrown away. Smart technologies will help the hospitality industry to reduce food waste, reduce costs, and be more environmentally friendly by reducing GHG emissions.
3.4. Circular hospitality 4.0

The linear economy should be transformed into a circular economy to allow reuse and recirculation of resources. Larsson (2018, p. 12) defines the circular economy as “an economic system where production and distribution are organized to use and re-use the same resources over and over again”. It can be considered a new way of consuming linked to a move to a low carbon economy. According to Preston (2012, p. 3) circular economy “involves remodeling industrial systems along lines of ecosystems, recognizing the efficiency of resource cycling in the natural environment” while it is seen as relying on three main principles (World Economic Forum, 2016). These are: maintaining and boosting natural resources through use of renewable rather than fossil fuel energy, and use of other sustainable methods; optimizing resources efficiency by circulating products, components and materials; and strengthening system effectiveness. Some studies (Ghisellini et al., 2016; Sakai et al., 2011; Su et al., 2013) highlight the three Rs of reduction, reuse, and recycling.

Application of circular economy principles in hospitality could result in more sustainable hospitality and tourism. Sustainability has for long focused mainly on energy use, water use and recycling. The circular economy would promote sustainable tourism and travel and savings on water and energy consumption by replacing non-renewable resources with renewable resources which would help to reduce carbon emissions, and waste and introduce zero km menus in restaurants (Vargas-Sánchez, 2018). According to Manniche et al. (2017) circular hospitality includes building and construction, refurbishing and redecorating, operational services and practices related to accommodating managers and staff, and interactions with guests.
The hospitality industry has begun to implement industry 4.0 technologies in order to improve data collection and automate systems to help reduce waste and energy and water consumption. Application of eco-innovation practices in hotels is important but not enough to achieve a circular business. Circularity must be central to the host-guest relationship. Hotels must involve their consumers in environmental issues and actions to contribute to sustainability. Consumers must be aware of more efficient use of resources. Consumers and the industry must have access to information to reduce the travel and tourism ecological footprint (Florido et al., 2019).

The implementation of technologies such as renewable energy systems and energy efficient lighting, cooling and heating will boost energy efficiency. This circularization will contribute to making the tourism industry more sustainable (Girard and Nocca, 2017). Some hotels have installed water control systems. Huge amounts of water are consumed by laundries where water accounts for approximately 35% of total energy consumed with 65% going on drying and finishing. Others are using smart showers; a recycling shower developed by OrbSys can save 90% on water consumption and 80% on energy compared to a regular shower. It operates as a closed-loop and recirculating system which enables reuse of wastewater. When the shower is turned on, the wastewater enters a filtration system. Recycling of wastewater would result in huge water and energy consumption savings (Manniche et al., 2017). Hamwells⁵ has introduced a circular shower which saves on both water and energy. Implementation of these and similar water saving technologies in the accommodation sector would result in more efficient energy and water use which would contribute directly to sustainability.

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⁵ See: [https://www.hamwells.com/en/](https://www.hamwells.com/en/)
Smart technologies can prevent food waste. Smart meters in kitchens can track kitchen waste and consumer plate waste. They provide information on what food is wasted, at what stage, and at what cost and on what food can be recycled. Hotels can adopt several circular economy initiatives such as kitchen appliances that optimize production, processing, and storage of food, smart fridges and storage facilities to keep food fresh for longer, packaging technologies to extend food life and inform users about the product footprint to allow more informed choices (Manniche et al., 2017).

The benefits of a circular hospitality industry 4.0 would result in reduced water and energy use and would reduce food waste all of which would reduce costs, and more efficient use of these resources which would contribute to sustainability and reduce the carbon footprint.

### 3.5. Minimizing transport and travel: Virtual Reality

Climate change is a serious threat which will have severe consequences for humans and ecosystems. Travel contributes to climate change including daily travel and tourism travel. It is estimated that tourism accounts for 5% of global carbon emissions (Peeters and Dubois, 2010). The biggest contributor to carbon emissions from the tourism sub-sector is transport which accounts for 75% of carbon emissions in this sector (UNWTO et al., 2008). Air travel is the main source of carbon emissions accounting for 40% of this 75% (Gossling, 2009). Emissions from international aviation are not included in the Paris Agreement (Lenzen et al., 2018) although it does set ambitious goals for all the parties to the agreement (UNFCCC, 2015; p.3; Article 2.1(a)): “Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.”
Paris Agreement aims to keep global warming below 2°C, and strategies should be implemented to achieve this objective. Action is need to change travel systems to minimize the impacts of climate change which means that travel companies and travelers must take action to move towards more responsible and sustainable travel practices.

Ben Youssef et al. (2020) highlight the short and long run effects of the COVID-19 pandemic in hospitality industry. In the short run, dramatic fall in flights (77% decrease on commercial flights from January to April), potential bankruptcy of airlines, hotel closures and cancelations of international events have affected the hospitality industry. Whereas, in the long term, consumer behavior will change and use of technologies will rise in the hospitality industry.

To achieve sustainable development will require use of recent technological developments. VR can offer tourist experiences and several studies look at the link between VR and tourism (Cheong, 1995; Dewailly, 1999; Guttentag, 2010; Huang et al., 2016). It has been suggested that VR could substitute for actual travel (Cheong, 1995; Sussmann and Vanhegan, 2000). Several works (Ja Kim et al., 2020; Kim et al., 2020; Kim and Hall, 2019) refer to tourism-related VR activities related to game playing, experiences, travel, exploring, looking at pictures, gaming, watching based on 3D 360 degree videos, drone videos, and holographic images. The latest VR innovations enable transformation of VR from a niche technology to an everyday experience. As a result of the spread of COVID-19 pandemic, tourism activities have been collapsed. Consequently, it is increased the interest for virtual tourism activities and it is expected to be increased also in the future (Ben Youssef et al., 2020) Most people can experience virtual city tours and visit tourist attractions from anywhere in the world using low-cost VR viewers. VR has great potential for mass virtual tours to tourism destinations (Tussyadiah et al., 2018). Sensitive sites and environments which are no longer accessible can be visited using VR (Perry Hobson and Williams, 1995; Sussmann and
Vanhegan, 2000). VR allows travel across time and travel to fantasy worlds (Cheong, 1995). It removes barriers to accessibility for elderly or disabled would-be travelers (Perry Hobson and Williams, 1995; Sussmann and Vanhegan, 2000).

Use of VR would contribute significantly to sustainability (Dewailly, 1999) by providing a low cost and environmentally friendly way of “traveling” (Wiltshier and Clarke, 2016). The development of VR has enabled tourism to integrate increasingly with the physical worlds. In addition to allowing individual experiences, VR would solve the problem of mass tourism and reduce degradation and overcrowding of heritage sites. VR would help disabled people and those on small budgets to access various destinations. In 2018, the French startup FlyView\(^6\) launched a VR that allowed tourists to see and feel what it was like to fly over Paris in a jetpack. Immersive video and a dynamic movie platform give the impression of real flight. South Carolina State Parks\(^7\) has launched a VR experience involving climbing Table Rock Mountain which allows tourists to experience one of the most strenuous hikes in the state from a chair in the visitor center.

Drones can also be used for virtual tourism; video cameras attached to drones’ record and capture pictures and aerial views of historical and natural sites and are an environmentally friendly technology (Kitonsa and Kruglikov, 2018). VR would save money, time, and the environment.

**Proposed research agenda**

Based on the five ways identified above to combat climate change, we propose a model (figure 2) which should be validated in future research. The first part of the model consists of application of industry 4.0 technologies to the hospitality sector, including CPS, the IoT, AR, VR, AI and robots, and big data which should increase energy and water use efficiency, reduce food waste, allow a circular model, and minimize travel and transport.

![Diagram of Proposed Model](image)

**Figure 2. Proposed model**

The second part of model shows that energy efficiency, water use efficiency, food waste reduction, and circularity are linked. *First*, implementation of circular hospitality 4.0 will have a significant effect on increasing energy efficiency and water use efficiency, and reducing food waste. *Second*, reducing food waste will increase energy efficiency and water use efficiency significantly. *Third*, more efficient water use will have a significant influence on increasing energy efficiency.
Finally, all of these aspects will enhance business performance (e.g. reduced costs from lower energy and water consumption, and reduced food waste). These three items combined with circular hospitality 4.0 and reductions to travel and transport will hugely reduce climate change by reducing GHG emissions.

**Concluding remarks and policy implication**

This paper examined the role of industry 4.0 technologies in the hospitality sector as a way of reducing climate change. While both adaptation and mitigation strategies to combat climate change are crucial, we focused on mitigation. We proposed a model of the potential effects of industry 4.0 technologies applied in the hospitality sector in order to reduce climate change.

Our main findings show the potential of these technologies in the hospitality industry to increase sustainability. The five applications proposed show that industry 4.0 could have major implications for efficiency increases and reduced carbon footprint. On the one hand, integration of CPS, IoT, AR, VR, AI and robotics and big data in the hospitality sector will allow customized services for consumers and reduce costs. On the other hand, implementation of hospitality industry 4.0 technologies will enable increased energy efficiency, more efficient use of water resources, reduced food waste, a move from the circular economy to circular hospitality 4.0, and lower levels of travel and transport – the main contributors to carbon emissions in the hospitality sector.

It will be necessary to implement a set of technologies, not a single technology; interconnected and interoperable technological systems will increase business opportunities and environmental performance. Their adoption must be part of a systemic change which will require deep
organizational change in the hospitality industry. The hospitality ecosystem must be designed as a smart system which includes all stakeholders to allow added value for the entire chain. Industry 4.0 offers a sustainable solution for the hospitality industry with appropriate implementation of technologies. Given the potential of these technologies to mitigate climate change we need policies to foster their adoption by the hospitality industry. Policymakers must implement innovative energy efficiency policies and programs for the hospitality industry to minimize or reduce energy use.

This paper suggests directions for further quantitative research. The proposed model should be validated and appropriate measures need to be developed. This study should be considered a preliminary exploration of the role of industry 4.0 in the hospitality sector in relation to climate change, based on qualitative analysis. We plan to conduct quantitative analysis to validate our proposed model and apply it to different countries to allow its components to be analyzed in more depth.

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