



Review

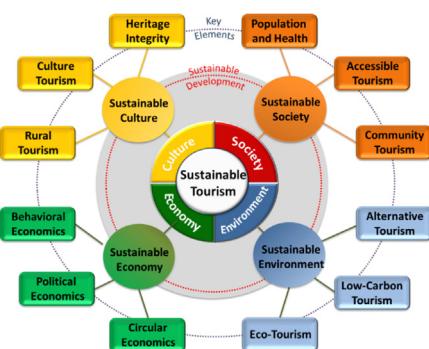
Advances and challenges in sustainable tourism toward a green economy

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HIGHLIGHTS

- Challenges and barriers in tourism sector toward sustainability are illustrated.
- A total of six key cross-disciplinary elements in sustainable tourism are proposed.
- Strategies, framework and details of KPI system for green tourism are provided.
- A case study of the Green Island, Taiwan toward a circular economy is presented.
- Transformative changes in tourism such as water-energy-food nexus are described.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper provides an overview of the interrelationships between tourism and sustainability from a cross-disciplinary perspective. The current challenges and barriers in the tourism sustainability, such as high energy use, extensive water consumption and habitat destruction, are first reviewed. Then the key cross-disciplinary elements in sustainable tourism, including green energy, green transportation, green buildings, green infrastructure, green agriculture and smart technologies, are discussed. To overcome the challenges and barriers, a few implementation strategies on achieving sustainable tourism from the aspects of policy/regulation, institution, finance, technology and culture are proposed, along with the framework and details of a key performance indicator system. Finally, prospects of the potential for tourism to contribute to the transformative changes, e.g., a green economy system, are illustrated. This paper shines a light on issues of importance within sustainable tourism and encourage researchers from different disciplines in investigating the inter-relationships among community/culture, environment/ecology, and energy/water/food more broadly.

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1. Introduction

1.1. Significance and importance of sustainable tourism

Travel and tourism have a tremendous contribution to our modern economical system. According to the statistics reported by the United Nations World Tourism Organization (UNWTO), global travel and tourism industry, including tourism-related business such as catering and cleaning, represents 9.8% of total global gross domestic product (UNWTO, 2017a) and 7% of global trade (UNWTO, 2017b) in 2016. They also create approximately 11% of the world's existing employment (direct & indirect) in 2016 (UNWTO, 2017a). However, this great contribution to economic development also has a significant impact on the environment and ecosystem. For instance, CO₂ emissions for global tourist trips including same-day visitors' amount to about 1302 million tonnes (Mt) CO₂ (Peeters and Dubois, 2010), corresponding to 5% of global anthropogenic CO₂ emissions in 2005, i.e., 26,400 Mt CO₂ (IPCC, 2007).

In fact, considering the amount of CO₂ emissions from tourism including transportation, as well as the great growth rates of tourists, its contribution to the climate change is not small comparing to that of all other sectors (Bows et al., 2009). Peeters and Dubois (2010) first developed a 30-year projection model based on an emission inventory made

for 2005. They found that improvements in technology alone cannot reach the targets of CO₂ emission reduction for sustainability. Without a radical shift, the future tourist travel system will not meet the significant CO₂ emission reduction required for avoiding dangerous climate change (Peeters and Dubois, 2010). In other words, immense transformations in not only transport modes but also destination choice are necessary (Peeters and Dubois, 2010).

Fig. 1 shows a roadmap of connecting tourism industry with sustainable development around the world. Since the late 1980s, the research in tourism field has given substantial focus on the issue of sustainability (or sustainable development) (Hall, 2010). At that time, the concept to connect tourism activity and the environment, known as "alternative tourism", was proposed and developed (Aall, 2014). The United Nations (UN) plan of action for "Sustainable Development Agenda 21" adopted at the Rio Conference in 1992. After that, the UNWTO had presented its perspectives on sustainable tourism. In 1996, a separate Agenda 21 for tourism, developed in a partnership with the UNWTO, the World Travel & Tourism Council (WTTC), and the Earth Council (EC), was published. Followed by this document, the Quebec Declaration on "Ecotourism" was announced at The World Ecotourism Summit in 2002, and the Davos Declaration on "Climate Change and Tourism responding to Global Challenges" was announced afterwards in 2007. Until the Rio + 20 in 2012, the outcome document "The Future We Want" largely

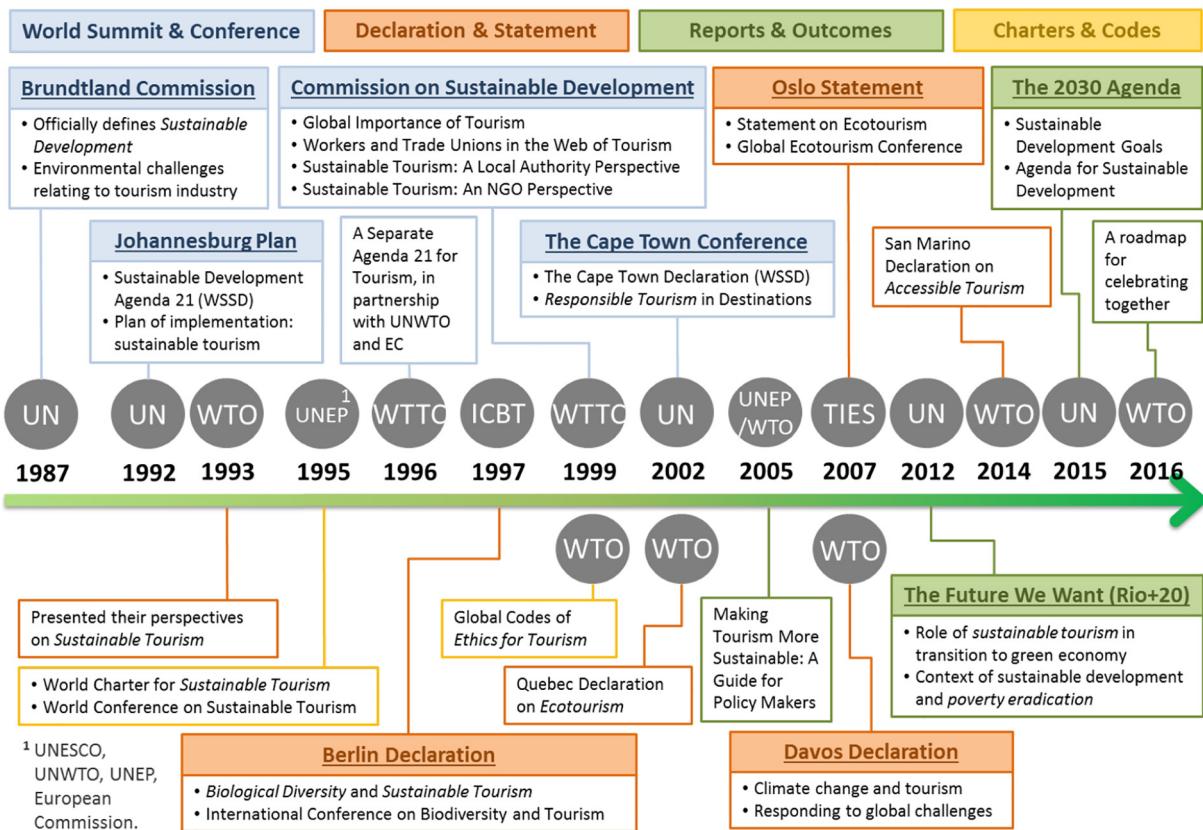


Fig. 1. Roadmap of connecting tourism with sustainable development around the world: principles, declarations, conventions, statements, and codes. Acronyms: WSSD (World Summit on Sustainable Development); UNWTO (United Nations World Tourism Organization); CSD (Commission for Sustainable Development); WTTC (World Travel & Tourism Council); UNEP (UN Environment Programme); TIES (The International Ecotourism Society); and EC (Earth Council).

promoted the role of tourism in the transition to a green economy in the context of sustainable development and poverty eradication. At present, however, interests in sustainable tourism among researchers are still limited, although tourism is among numerous stakeholders such as tourism industry advocates, enterprises and tourists (Buckley, 2012).

With particular reference to the Sustainable Development Goals (SDGs) and the broader 2030 Development Agenda (United Nations General Assembly, 2015), the UNWTO recommended five central pillars to which tourism should stand to make a significant and lasting contribution to achieve the sustainable development (UNWTO, 2016; UNWTO, 2017a): (i) inclusive and sustainable economic growth, which is linked to SDGs 8, 9, 10 and 17; (ii) social inclusiveness, employment and poverty reduction, which is linked to SDGs 1, 3, 4, 5, 8, and 10; (iii) resource efficiency, environmental protection and climate change, which is linked to SDGs 6, 7, 8, 11, 12, 13, 14, and 15; (iv) cultural values, diversity and heritage, which is linked to SDGs 8, 11 and 12; and (v) mutual understanding, peace and security, which is linked to SDGs 18. Saarinen and Rogerson (2013) presented a review on the contribution of tourism to the UN Millennium Development Goals such as poverty alleviation. Especially in developing countries, implementation of sustainable green tourism should be considered as the green practice for addressing poverty, employment and economic diversification (Honeck, 2012). It is noted that the overall tourism industry accounts for 47% of economy of developing countries in 2011, and optimistically 57% in 2030, equivalent to over one billion international tourist arrivals (UNWTO, 2002).

1.2. Definitions of tourism activity

In order to be accepted globally, a sustainable, desirable and politically appropriate tourism should be developed. Sustainable tourism activities principally cover the environmental, economic, social and

cultural aspects of development. Fig. 2 illustrates the concept of these four sustainability aspects for tourism. Since natural resources may be intensively exploited in the tourism business, tourism activities would sometime pose major impacts on the environment, ecosystems, economy, society and culture. Potential environmental impacts broadly range from global ocean pollution to localized disturbance in endangered plant and animal species in protected areas (Buckley, 2011). Therefore, a holistic balance among these four dimensions should be considered to guarantee the short-term and long-term development of sustainability for the tourism sector in the face of climate change.



Fig. 2. Four conceptual aspects required for achieving sustainable tourism.

The principles of sustainable development should apply to various types of tourism activities and operations by establishing long-term and short-term strategies and programs (UNEP, 2002). In this section, the definitions of sustainable tourism, ecotourism, culture tourism, rural tourism, and community tourism are briefly illustrated.

1.2.1. Sustainable tourism

Sustainable tourism is reducing the negative effects of tourism activities on the environment, society and economy to achieve ecologically sustainable, economically viable, as well as ethically and socially equitable. The UNEP and UNWTO (2005) conceptually defined sustainable tourism as “development of tourism activities with a suitable balance between these the dimensions of environmental, economic, and socio-cultural aspects to guarantee its long-term sustainability.” It must fulfill the needs of the present tourists and destinations while providing opportunities to further development in the future, as well as maintaining heritage integrity, ecological integrity, biological diversity, and life-support system. In fact, tourism development should concerns sustainable development that aims at the continuous improvement of tourists’ satisfaction (Sharpley, 2000). The Green Tourism Association of Taiwan also defines the green tourism as “tourism activities that minimize the environmental impacts, and reduce energy usage and carbon emission while enjoying ecology-humanity-culture integrity.” In particular, a special attention to the relationship between tourists’ activity and nature should be taken to adopt operational strategies in a spirit of harmony and respect toward the green tourism.

1.2.2. Ecotourism

The term ecotourism was originally proposed in the late 1970s. It is seen as a type of nature-based tourism, and has been becoming as a way to protect the natural landscapes of a specific region. In fact, ecotourism refers to a segment within tourism sector with a special focus on environmental and ecological sustainability, thereby attracting lots of attention from tourists as an alternative tourism. Ecotourism could play an important role in green growth for developing countries with significant natural endowments, since these activities do not normally require an immense capital outlay and investments. It can also connect to the local communities who may lead tourism activities and operations of ecosystem preservation. By doing this, ecotourism can generate employment for the unskilled workforce in rural communities and create numerous export opportunities in remote locations to ensure a green economy. Therefore, ecotourism should be regarded as a suitable industry for promoting economic development in developing countries with capital scarcity and natural resource abundance (Viljoen, 2011).

1.2.3. Rural tourism (or agro-tourism)

Rural tourism emphasizes healthy activities and welfare-expressed life in the pleasure of clean air, fresh water, landscape, culture and traditions. Thus, rural tourism shares similarities to ecotourism but with a primary appeal toward traditionally managed and cultural landscapes. The modern model of rural tourism usually links up economically with existing farms, known as agro-tourism (Aall, 2014). Healthily food in a rural farm can be used as a source of satisfaction and relax for tourists (D'Alessandro, 2016). Agro-tourism also may involve growing, harvesting and processing local food or crops on farms. In addition, numerous farmers provide a homestay opportunity at scenic beauties and wilderness areas and educate the tourists on farm life and culture such as religious and cultural tradition or folklore. These practices can directly contribute to farm income, and provide farmers with a way to sale farm products (Scope ACP, 2011). For instance, one niche market for agro-tourism is wine tourism, usually involved in the tasting and/or purchase of local wine near the source of production (UNEP, 2013). Although tourism inspires numerous activities, the tourist consumption may pose negative and irreparable impacts on the landscape. The ideal rural tourism should encourage creative activities and green practices

of making farms sustainable in keeping with the historical and natural setting (D'Alessandro, 2016).

1.2.4. Culture (heritage) tourism

Culture tourism is increasingly developed as a way to protect the heritage of a specific region (Light, 2017). Natural and cultural heritage should be considered as a basis for sustainable tourism. Natural heritage comprises vegetation, wildlife, geological and hydrological phenomena, as well as natural events such as climate, astrological and volcanic incidents. Similarly, cultural heritage includes living cultures (such as festivals, rites, education, religion, costumes, legends, behaviors, habits, music, dances and culinary culture), immobile historical monuments (such as parks, gardens, buildings, facilities and archaeological sites), and movable historical monuments (such as paintings, sculptures, artwork, handicrafts, agricultural tools, industrial machines, and documents/objects).

1.2.5. Community tourism

The concept of community can be applied to the tourism. In community tourism, a local community is responsible to develop initiatives and manage the itinerary of tourism activities (Aall, 2014). Community-based tourism links the goals of balanced tourism development with great ecological considerations by existing business models. In particular, in community tourism, the concept of sustainable development is applied to improve the life quality of residents by maintaining the natural and built environment, providing a high-quality experience for tourists, and optimizing local economic benefits (Park and Yoon, 2009).

1.2.6. Others

At present, new terminologies for tourism activities keep being created and still under-researched areas in tourism studies, such as accessible tourism (Polat and Hermans, 2016), responsustable tourism (Mihalic, 2016), geo-tourism (Newsome and Dowling, 2010) and maritime wildlife tourism (Trave et al., 2017). They typically require a multidisciplinary approach to understanding their themes and scopes combined with the sustainable tourism approach. For instance, Polat and Hermans (2016) developed a sustainable accessible tourism model to evaluate the potential ways for disabled people to intensively join in (or be accessible to) tourism activities with the highest level of experience. “Responsustable tourism” was defined by merging two words, i.e., responsible (practice and behavior-based) and sustainable (concept and values-based) (Mihalic, 2016). This new terminology added the sustainability value to the behavioral concept by connecting responsible behavior with the sustainable tourism concept. Moreover, an integrated sustainability-responsibility model, so-called the Triple-A (Awareness, Agenda and Action) model, was proposed to evaluate the performance of a responsible tourism destination or firm on the implementation of sustainability agenda. Furthermore, like geomorphological and geological-focused tourism, the concept of “geo-tourism” was promoted by the National Geographic Society based on the sustainable tourism while including additional principles to secure the integrity of place (Aall, 2014). Similarly, the wildlife tourism emphasizes the practice of observing wild animals in their natural environment. If conducted responsibly, wildlife tourism can provide economic benefits to local communities while simultaneously contributing to conservation efforts (Ballantyne and Packer, 2013).

1.3. Objectives of this review

To achieve the 2030 Sustainable Development Agenda, the UNWTO has defined three priorities for the tourism sector: (i) promoting safe, seamless and friendly travel, (ii) deploying innovative technologies in tourism, and (iii) embracing the sustainability agenda (UNWTO, 2017b). To promote and accelerate the development of tourism industry toward sustainability, this article provides a comprehensive review on the trends and outlook for tourism activities toward sustainable

development. The challenges and barriers in tourism sustainability such as large energy use, greenhouse gas emissions and extensive water consumption are first illustrated. In response to the aforementioned challenges, several key cross-disciplinary elements toward green tourism, including renewable energy, sustainable mobility, green building, green infrastructure, green agriculture and information communication technology, are then identified. After that, implementation strategies on developing sustainable tourism and comprehensive performance evaluation programs are proposed and illustrated. Finally, perspectives and prospects on sustainable tourism, including transition to a green economy, sustainable material management, and water-energy-food nexus, are provided.

2. Challenges and barriers in tourism sustainability

Tourism development and management would encounter a multitude of significant sustainability-related challenges for policy-makers and planners. In fact, the challenge of sustainable tourism is to mitigate the negative impacts by enhancing the tourism's benefits into the right directions (ETE, 2009). For instance, an economically profitable and ecologically sustainable industry can provide satisfying experiences for visitors and increase quality of living in local communities (Lim and McAleer, 2005). Other pressing challenges may include high energy consumption, food waste, overall waste management, weak business environment (especially in developing countries), shortage of skilled labor, limited access to finance, and low levels of investment. The UNEP indicated that the challenges are currently becoming more difficult due to the multiple crises worldwide, e.g., climate change, economic recession, fuel/energy crisis, food crisis, and water crisis (UNEP and UNWTO, 2012). In this section, a total of six potential challenges in promoting ecotourism in the transition to a green economy are illustrated and summarized.

2.1. Large energy use and greenhouse gas emissions

Tourism is a significant contributor to the increasing greenhouse gas (GHG) emissions in the atmosphere at the global scale, being attributed from travel, transport, accommodation, and its related activities. In fact, the tourism sector accounts for about 5% of global CO₂ emissions but, considering the radiative forcing of all GHGs, the overall contribution of tourism activities to global warming potential is estimated to be 5.2–12.5% (UNEP and UNWTO, 2012). It is noted that the future growth of tourist-related CO₂ emissions should depend upon three major factors (Peeters and Dubois, 2010): (i) number of tourists; (ii) number of trips of long haul tourism; (iii) frequent holidays for a shorter length of stay.

Energy use and associated GHG emissions in tourism-related activities are attributed from three major subsectors: transport, accommodation and activities. Their GHG emissions comprise a complex mix of (i) travel motives, e.g., business, leisure, or visiting friends and relatives, (ii) geographical patterns, e.g., international/domestic and short/long travel, (iii) temporal ranges, e.g., same-day or overnight trips, and (iv) purposes of the tourism activities, e.g., business, conferences, festivals, shopping or leisure. It is noted that the most emissions related to the transport of tourists are aviation, accounting for 40% of tourism's contribution to CO₂ (i.e., direct energy use), followed by cars (32%) (UNWTO et al., 2008). Emissions from tourism-related transport can be determined by multiplying travel distances with the emission factors. For transport in the EU, averaged emission factors for air, car, rail, and coach transports are 0.129, 0.133, 0.027 and 0.022 kg CO₂ per kilometer, respectively (Peeters et al., 2007). Regarding the accommodation, most energy is consumed in space heating or air conditioning (up to 50% in some cases), followed by being used for hot water or cooking (Beccali et al., 2009). The values of energy use in hotels can vary considerably among different countries, e.g., 32–112 million joule (MJ)/guest-night in Italy (Beccali et al., 2009); 32–110 MJ/guest-night in New Zealand

(Becken and Hay, 2007); 119 MJ/guest-night in Germany (Gössling, 2010); and 65–457 MJ/guest-night in Vietnam (Trung and Kumar, 2005).

2.2. Extensive water consumption

On a global basis, the amount of water use by tourism is far less than that by agriculture, industry or domestic (city) use. However, in some regions, the water use by tourism sector can be the largest proportion among the total water use. The major water consumptions in tourism can be commonly found in golf courses, irrigated gardens, swimming pools, spas/wellness facilities and guest rooms (e.g., shower). Although tourism-related water consumption is little evaluated in the literature, available reports indicate that most of the direct water consumption by tourism is contributed by accommodations (Gössling, 2005). Gössling (2005) found that global water use in accommodations for international tourism is approximately 1.3×10^9 m³ per year. In the United States, for example, 60% of water consumption in tourism and recreation (i.e., 568 million m³ of water per year) is attributed to accommodation such as shower, swimming pool, landscape and laundry, while 13% of water consumption is for food-related service (UNEP, 2003). It is noted that direct water use per tourist varies widely, in the range between 100 and 2000 L per guest night (UNEP and UNWTO, 2012).

Regarding the purposes of water use, little information and data are available. A study in Tanzania indicates that a half of the total water consumption in hotels (i.e., 465 L per day per tourist) is used for continuous irrigation of gardens (Gössling, 2001), due to poor storage capacity of the soils and high evaporation. Another 20% of direct water consumption in hotels (i.e., 186 L per tourist per day) is used for showers, toilet, and tap water. In contrast, the water consumptions in guesthouses for watering gardens and direct uses are 15% (i.e., 37 L per tourist per day) and 55% (i.e., 136 L per tourist per day) of their total water use (Gössling, 2001). Furthermore, various tourist activities such as golf can greatly enhance overall water use by tourism (Diaz et al., 2007).

2.3. Inappropriate waste management and treatment

The increased number of tourism industry has resulted in an increase of waste generation (UNEP and GPA, 2006). Although waste management and utilization have been one of the well-recognized challenges in the industry, the issue of waste management and treatment is still a big challenge. It is noted that over one kilogram of solid waste is daily generated for every international tourist in Europe, and up to two kilogram per person per day for the United States (UNEP, 2003). Wastewater management and treatment are great challenges, even in mature and wealthy-country destinations. Tourism can directly affect the quality of water through the discharge of untreated wastewater (sewage) and freshwater abstraction. Water pollutions from tourism activities may include nutrient loads combined with organic/inorganic particles, chlorine loads from swimming pool, and chemicals or surfactants used to dissolve fats and oils (UNEP and UNWTO, 2012). Furthermore, water quality can be indirectly influenced, for example, via the over-use of underground water, and thus lead to detrimental impacts such as saltwater intrusion, land subsidence and deterioration of water quality.

2.4. Loss of biodiversity and habitat destruction

Biodiversity can provide us with a wealth of natural resources that are greatly important for the tourism sector. However, a large-scale tourism also could have detrimental impacts on biodiversity, habitat and natural landscape, such as coral reefs, mountains, rainforests, wetlands, arid and semi-arid ecosystems (UNWTO, 2010). For instance, coastal wetlands have routinely been damaged or destroyed due to the construction of beach resorts (UNEP and UNWTO, 2012). In Dubai,

the expansion of the tourism sector is damaging the marine habitat, burying coral reefs, oyster and sea-grass beds, threatening other marine species, increasing the turbidity of coastal waters and disrupting natural currents (UNEP and GPA, 2006). In tourism industry, the challenges for maintaining biodiversity include (i) introduction of invasive alien species, (ii) disturbance of wildlife (iii) transformation of land use for tourism activity, (iv) overexploitation of natural resources for water, food, materials and recreation, and (v) water pollution and waste generation (UNWTO, 2010). Failure to incorporate biodiversity concerns in destination management would pose severe environmental impacts, lead to conflict with local communities, and reduce the value of creation potential (UNEP and UNWTO, 2012). It is noted that the maximum capacity of a habitat and the tolerance limits of the particular species involved are usually overlooked during the development of the management framework (Trave et al., 2017).

2.5. Threats to heritage management and cultural integrity

Heritage, including natural, built and cultural heritage, is affiliated with a region or a society based on its history. In fact, the natural and cultural heritage of a specific area is usually the main motivation for a tourism activity, especially for cultural tourism or congress tourism. Cultural vulnerability is a critical issue for indigenous cultures and cohesive communities around the world. Rural or remote communities often possess unique heritage (e.g., cultural attributes) that may be interesting to tourists but which are at a high risk of disappearing. Also, the development and construction of infrastructure for tourism may threaten the integrity of heritage (ETE, 2009). With the growth in tourism activities, their impacts on vulnerable heritage have been taken seriously by governments, tourism-related sectors, communities, and cultural groups.

2.6. Lack of communication channels and information platforms

The lack of communication channels can result in a number of challenges. For instance, if the communication channels within the supply chain in agro-tourism are not transparent and the middlemen are the dominant stakeholders in the chain, farmers would not have control over marketing their production (Sanches-Pereira et al., 2017). The lack of direct communication channels could also increase conflicts between local communities. On the other hand, the lack of information exchange platforms would lead to an inefficient tourism system and insufficient public awareness. For example, if farmers lack sufficient technical knowledge of green agriculture (such as improved production techniques, pest and disease control, soil fertility assessment, and harvesting and post-harvesting techniques), they would face several critical issues, such as unsustainable production, low productivity and crop losses. Similarly, the lack of environmental awareness from local communities and tourists would lead to insufficient legal framework, improper management, cultural insensitivity, and heritage deterioration (ETE, 2009).

2.7. Summary

Developing sustainable ecotourism is a big challenge for planners and policy makers. As discussed in this section, a total of six specific challenges that need to be resolved through the green tourism activity: (i) large energy use and greenhouse gas emissions; (ii) extensive water consumption; (iii) inappropriate waste management and treatment; (iv) loss of biodiversity and habitat destruction; (v) threats to heritage management and cultural integrity; (vi) lack of communication channels and information platforms. These challenges can potentially be regarded as an opportunity to introduce green investment in the economies. It is important to diminish "brown" economies with traditional business models, mostly on low energy efficiency, fossil-based energy resources, extensive and unsustainable use of resources, and a high

risk of extreme climate change. To provide a unique space for green tourism and economy, potential opportunities include (i) sizing and growth of the sector, (ii) changing consumer behaviors and patterns, and (iii) addressing local development and poverty reduction.

3. A cross-disciplinary approach toward sustainable tourism

Tourism activities (e.g., construction of massive transport and building infrastructure) could bring severely negative consequences to natural environment (Hashemkhani Zolfani et al., 2015), such as degradation of landscapes, destruction of habitat, and pollution of coastal zones. Fig. 3 shows tourism activity chain and its connection to sustainable development. To mitigate the impacts of tourism, the concept of "greening" or "sustaining" should be introduced in the tourism chain. Numerous key elements, such as energy, transport, buildings, infrastructure, agriculture, and smart technologies, play imperative roles in achieving sustainable tourism. In this section, hence, the roles of these cross-disciplinary elements on sustainable tourism are discussed.

3.1. Renewable energy (green energy)

Energy is one of the vital elements in tourism activities. In other words, there is a close relationship between renewable energy and sustainable development in tourism. To achieve GHG emission reductions in tourism in line with global climate policies, considerable change in overall energy use pattern in the tourism system and a switch to renewable energy resources are required. Tourism industry has been already leading the way in the innovative sustainable energy initiatives. For instance, numerous green practices can place tourism at the forefront of such transformation (UNEP, 2013; UNWTO, 2012): (i) energy-efficient aircraft, (ii) a shift to renewable energy, (iii) new-generation energy technologies, and (iv) measures of energy efficiency in hotels.

The currently available renewable energy technologies include solar, wind, hydro, bioenergy, ocean and geothermal energy. For instance, solar energy devices can harness the power from the sun to generate electricity either directly by photovoltaic (PV) cells (Shih et al., 2016), or indirectly through concentrated solar power (Fuqiang et al., 2017). The variety of renewable energy resources provides a flexible array of options for their use. Nonetheless, the main concern to integrate the electricity generated from renewable energy into the grid is the safety, security, stability and sustainability (4S) of supply due to their intermittent characteristic strongly depending on weather conditions. In other words, the issue of renewable energy storage should be critically considered when developing a renewable energy project. The grid-scale energy storage devices, such as batteries, can reduce the uncertainty of non-dispatchable power sources in a number of ways for intermittency mitigation and integration management for renewable energy.

In addition, the implementation of renewable energy sometimes would encounter other challenges, such as conflict to national land-use plans (Shih et al., 2016) or managing inhabitants' opposition to the implementation of a project (Rizzo, 2017). Also, the land use conflicts between landscape/built heritage and renewable energy implementation should be critically assessed. For instance, a comparative analysis of space-constrained and tourism-driven regions could provide a better understanding of the challenges and capacity that governments would face. Furthermore, Gasparatos et al. (2017) identified the impacts of various renewable energy resources on ecosystems and biodiversity, as well as on the transition to a green economy. They made a point that some negative impacts of renewable energy on biodiversity do exist (i.e., trade-offs between renewable energy and biodiversity), which need to be considered when developing renewable energy policies.

3.2. Green transport and sustainable mobility

Sustainable tourism is tightly connected with the concept of sustainable mobility since tourism is always linked to travel such as

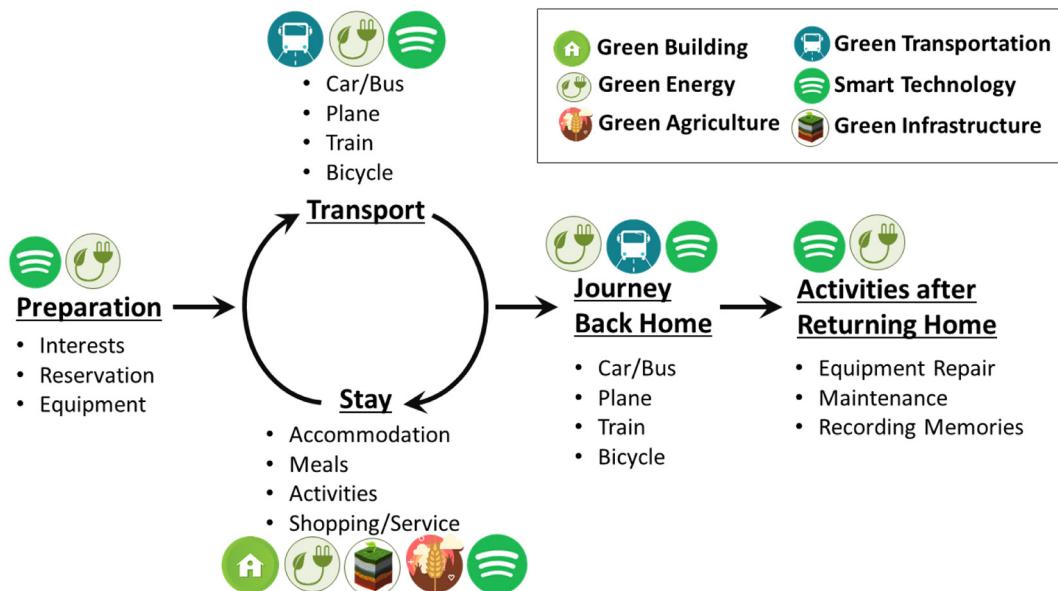


Fig. 3. Tourism chain and its connection with sustainable development.

air transport and buses. It is noted that 72% of tourism's CO₂ emission comes from transport, 24% from accommodations, and 4% from local activities (Peeters and Dubois, 2010). In particular, air transport, only used in 17% of the total number of tourism trips, alone produces 43% of total CO₂ emission. Tourism and aviation are expected to share a great proportion of CO₂ emissions unless significant changes in the emission trajectories are made (UNEP and UNWTO, 2012). The amount of emissions from international transport depends on travel mode, fuel efficiency, international business, emission offset initiatives, and externalities for carbon footprint of global tourism.

The key strategies on achieving sustainable transport in the tourism sector around the world include implementation of (i) green practices, (ii) airline liberalization, or (iii) economic instruments such as Air Passenger Duties (APD) in the UK (Seetaram et al., 2014) and Passenger Movement Charge (PMC) in Australia (TTF, 2012). Green practices of transportation can revolve around efficient use of resources or modification of the transport structure to provide more sustainable travel choices. These green practices require production of innovative electric vehicles that utilize renewable energy (such as solar, wind and hydro-electricity), management of privately owned vehicles and dedicated public awareness and participation. For airline liberalization, it can promote public investments in improving the infrastructure and efficiency of air travel, such as airspace and air-traffic management (WEF, 2009), which can obtain significant benefits. For economic instruments, the UK's APD has been mainly justified as environmental taxation for fixing externalities caused by the aviation sector, while the Australian PMC is aimed at financing border public agencies. In the case of PMC, however, tourism industry could gain or lose from the increase in passengers' tax, since it depends on three major factors (Forsyth et al., 2014): (i) the price elasticity for travel demands, (ii) the balance between inbound and outbound travels, and (iii) the extent to which domestic tourism is a substitute for international tourism. It is noted that the degree of substitutability among tourism services by different destinations could play an important role in PMC because it strengthens an origin's incentives for taxation, while weakening destinations' incentives (Álvarez-Albelo et al., 2017).

On the other hand, tourism is recently connected with the concept of sustainable mobility (known as the mobility nexus). The convergence between tourism travel and information/communication constitutes a key feature of a mobile society (Germann Molz and Paris, 2013). Recent advances in the information technology, e.g., wireless connectivity, sensor technologies, cloud computing, computer graphics and

smartphones, have made "mobile-augmented reality" more accessible to a mass market (Yovcheva et al., 2012). Hannam et al. (2014) provided an overview of multiple mobilities that may be involved in tourism mobilities. They found that tourism mobilities can involve the use of mobile methodologies because tourists now tend to bring mobile devices on their trips and fluidly switching between corporeal and mediated co-presence with distant social networks.

3.3. Green building

Building, one of the most important human activities, plays an imperative role in the formation of social environment and tourism industry. Buildings represent a high potential for energy savings; for instance, in Europe, buildings consume 40% of the total energy and emit 36% of GHGs (UNWTO, 2017b). As a result, improvement of energy efficiency in buildings (e.g., hotels) is an effective approach to reducing GHG emissions (Si et al., 2016). With green building practices, it is expected that environmental footprint of buildings can be significantly improved, i.e., reducing energy use by 30–50%, CO₂ emissions by 35%, waste generation by 70%, and water consumption by 40% (Varma et al., 2014). In general, the green building practices are accepted from the viewpoint of (i) energy and resource efficiency, (ii) improvement of ecological and environmental quality, (iii) waste reduction, and (iv) health improvement of occupants during the building life-cycle (Mao and Yang, 2011; Thilakaratne and Lew, 2011).

From the perspective of hotels, numerous green practices can be considered; for example, guests could be encouraged to re-use towels, or be informed that linen is not changed daily. Hotel-restaurant menus and letters addressed to the guests can be made by recycled paper. Similar green practices can be found in the Nearly Zero-Energy Hotels (nZEH) project. This project is initiated by the Intelligent Energy Europe Programme of the European Commission, and aims to support hotels in Europe to comply with the nZEB (nearly-Zero Energy Buildings) regulations (UNWTO, 2017b). It is noted that all EU Member States are required to meet the nZEB by 2020. In addition, D'Alessandro (2016) illustrated the development of an agritourism project in the Campania region, where fusion between landscape and architecture was served as the basis of the tourism. In this project, the main structure of agritourism was made with respect to green building principles, such as light-emitting diode lamp, composite windows, plant-based insulating materials, and TECU® copper alloys (which can provide stunning effects and colors to deliver the ultimate cladding style and provide protection

against the harshest of elements) and PV panels on the roof of a building. [Kim et al. \(2016\)](#) revisited the relationship between the green practices in the hotel industry and the satisfaction of tourists in a realistic setting. The results indicated that a higher deployment of green practices could enhance the satisfaction of customer; however, it does so only indirectly to some degree.

3.4. Green infrastructure

Infrastructures (such as trails, visitor centers, resting places, parking lots, camp grounds and vista points) allow individuals to visit an area and increase the ecosystem-service benefits associated with its recreational use. When talking about the infrastructure for visitors in protected areas, particular precaution is necessary due to the high vulnerability of natural attributes. In fact, green infrastructure provides opportunities for cities to be designated as protected tourist areas. The term “green infrastructure” refers to the interconnected networks of green spaces that can provide multiple benefits such as storm water management, improvement of water quality, conservation of wildlife, and provision of human recreation. Green infrastructure can be in the forms of natural, semi-natural or artificial networks of ecological systems with multifunction. Within these protected areas, various types of green infrastructures and practices, such as green street (tree planting on streets), bioswales, permeable vegetated surfaces, detention basins and green corridors, can logically be incorporated under a national program ([Serra-Llobet and Hermida, 2017](#)).

The key concept of implementing green infrastructure for sustainable tourism is the strategic use of both the existing natural elements and newly constructed elements to provide benefits of open space, air quality, and wildlife habitat. For instance, [Setyaningsih et al. \(2015\)](#) have established a model formulation of the tourist development through the low impact development (LID) to be put into realization of an eco-green and sustainable tourism. Also, US cities are increasingly implementing the LID to meet stringent requirements of water quality standards for cities with combined or separated sewer ([Green Nylen and Kiparsky, 2015](#)). Similarly, governmental plans linking into an ecological network or establishing a new protected area should be declared national objectives, alongside with conservation of unique heritage and landscapes ([Angelstam et al., 2017](#)).

3.5. Green agriculture

Both tourism and agriculture are important contributors to the local economy development. In particular, implementation of green agriculture plays an important role in achieving sustainable tourism. Sustainable agriculture emphasizes the provision of enough food (or agri-food products) and ecosystem services for present and future societies ([Koochafkan et al., 2012](#)). For instance, integrated pest management and organic production techniques are key elements in the scope of sustainable green agriculture. They can result in the reduced use of expensive chemicals and fertilizers, thereby increasing profit margins and reducing the risk of farmers' health and the local environment.

Especially for small-scale agricultural producers, the tourism development can provide great opportunities to increase incomes by marketing their agricultural products (such as fresh fruit, vegetables, flowers, and ornamental plants) to the local tourism sector. An increase in local agri-food production also might have a positive effect on local tourism. For instance, the organic products such as vineyard, the winery, the bio garden can be the selling points of the tourism. Therefore, establishing a linkage between agricultural products and rural tourism could contribute to the economic development of the area. However, numerous countries, such as Ghana ([Asiedu and Gbedema, 2011](#)), still lack implementation strategies to set these linkages up; therefore, tourism industry often ends up importing agricultural products.

Recently, the concept of an agribusiness model that brings up eco-agro tourism has been proposed. An institutional framework linking

tourism and agriculture sectors at multiple levels (i.e., country, region, and community) should be established to generate net benefit for small-scale farmers. Also, it is critically imperative to raise public awareness and to build citizen's capacity for attaining a high level of consciousness and knowledge in support of the implementation of linkages between tourism and agriculture. To promote green agriculture in sustainable tourism, [Sanches-Pereira et al. \(2017\)](#) proposed a set of potential thematic strategies: (i) public awareness and citizen's capacity building, (ii) start-up drivers, (iii) public-private partnerships and destination level cooperation and action, and (iv) effective promotion of pro-poor tourism and branding. On the other hand, for the tourism service providers with regard to locally-sourcing agri-food products, several factors are important ([Hüller et al., 2017](#)): food safety standards, quality, quantity, price, visual appearance, status of the producer, and documentation.

3.6. Smart technology

Recent technology developments in the areas of electronics and information and communication technology (ICT), such as internet of things (IoT) and wireless sensor networks (WSNs), have accelerated the transition to a digital world (so-called the digital age), and enhanced the appearance of information networks toward sustainable tourism. In fact, the ICT has increasingly been incorporated into tourism-related business, such as travels, experience feedback of tourists, operations and management of tourism firms ([Leung et al., 2013](#)). The scope of ICT encompasses the internet sphere and the mobile wireless networks. In general, it means all technologies that allow organizations and people to interact to each other in the digital world, covering software, hardware, transactions, communications technology, data, internet access, and cloud computing.

The importance of smart technology in economic development and business growth has been monumental; in fact, it continues to revolutionize all parts of the conventional tourism to smart sustainable tourism. For instance, the lack of practical information, such as the amount of tourists, is one of the biggest gaps in understanding and managing the impacts from tourism. The ICT industry plays a key role in data collection and analysis. For collection of data, WSN devices enable the continuous monitoring from small (a certain area) to global scale. They may be flexible, inexpensive, and easily deployed and support self-organization ([Xue and Hassanein, 2006](#)).

The real-time monitoring system, one of the applications of WSNs, is extremely important in metering environmental parameters in each tourist location. These networks use the environmental monitoring system based on an array of sensor networks and/or the interconnection of networks involved with heterogeneous wired and wireless techniques. For instance, [Novas et al. \(2017\)](#) developed a real-time monitoring system allowing the registration of numerous metadata such as temperature, relative humidity, wind speed and direction, CO₂ concentration, atmospheric pressure, amount and intensity of rainfall, presence and visitor count. The monitoring system is conceptualized for presenting the above metadata via the Internet in real time anywhere. This real-time system also can monitor over time the cave environment to evaluate the relationship between a sustainable tourism and the natural environment. Similarly, [Cama et al. \(2013\)](#) developed a wireless network for continuous monitoring of important environmental parameters, such as humidity, temperature, total solar radiation, photosynthetically active radiation and soil moisture, in the Amazon. Within the Peruvian Amazon rainforest, this is the largest permanent wireless network with a coverage of 450 km to evaluate the consequences of global climate change.

4. Strategies on sustainable tourism

Sustainable tourism can provide effective resource management, while simultaneously minimizing negative externalities to an area's

environmental and cultural integrity. In addition, sustainable tourism can generate “green” income or become an important source of export growth especially in developing countries. In this section, implementation strategies on development of sustainable tourism from the perspectives of policy/regulation, institution, finance, technology and culture are proposed.

4.1. Governance, policies and framework for sustainable tourism: reliability and security

Sustainable tourism could play an important role in establishing an integrated approach to policy, regulation and management for tourism development, thereby providing ways to secure positive benefits (Bramwell and Lane, 2012). Effective governance, policies, frameworks and tools need to be in place to plan, guide, support and coordinate development of sustainable tourism. Also, development of tourism adaptation measures to climate change (including societal adaptation) is important (Weir, 2017). For instance, the role of tourism industry on CO₂ emissions largely depends on the adaptation of sustainable tourism policies and efficient management. In addition, policy frameworks within an individual country should ensure that tourism and its promotion are soundly integrated in national policies, strategies and programs, and must be set up on evidence. In other words, data collection, analysis and monitoring are particularly important to propose clear objectives and sound plans on sustainable development and growth.

Governments and relevant authorities must keep reviewing the national policies, such as renewable energy supply and transport development, to ensure long-term reliability, security and sustainability of necessary factors in tourism. The visions of tourism policies should be consistent with the strategic goals of national economic, social and cultural development. As shown in Table 1, a total of eight essential factors, including food, clothing, accommodation, traffic, education, entertainment, purchasing and charity, should be considered in the development of sustainable tourism. For instance, from the perspective of purchasing, buying local products can reduce the GHG emissions by 4–5% due to the great emissions during the production and transportation of food (UNWTO, 2017a).

In addition, it is imperative to integrate sustainable consumption and production (SCP) patterns in tourism policies and frameworks. The SCP emphasizes the systematic change by decoupling economic growth from environmental degradation and applying a life-cycle approach by accounting all phases of resource use (Pan et al., 2015). This is in cope with the major theme of SDG-12, and should be particularly incorporated with the concept of sustainable materials management (SMM) toward a circular economy system (CES). SMM is a framework to sustainably manage materials and products throughout the entire life-cycle, which should be applied in tourism sector to deal with waste management issue. Also, supporting sustainable tourism while phase-out of the heavy polluting enterprises can effectively ensure the movement toward the CES (Su et al., 2013). In China, for instance, policy formulation in tourism sectors lacks the ability to systematical control on the production factors, such as land use, technology, capital and talent (Tang, 2017).

Furthermore, internationally recognized standards and criteria should be adopted and harmonized for the tourism sector. This can provide for awareness and consciousness about the practical aspects of sustainable tourism, thereby enabling the monitoring of tourism operation and management (UNEP, 2013). In addition, dialogue and capacity building is an important task that should be included along the formulation and implementation of educational policies to promote the development and contribution of sustainable tourism. Governments, non-government organizations, and the private sector can advise on the development of training programs and information systems, and help to build the capacity to manage tourism. Also, evolution of research and education is needed to spearhead changes in practice related to sustainable tourism (Moscardo, 2016).

Table 1

Essential factors in sustainable tourism and their connections to cross-discipline elements.

Necessities of tourism	Principles toward sustainability	Cross-discipline connections ^a
Food (Eating)	Eat organic (to reduce the soil pollution), locally (food should not be imported over greater distances), and seasonal.	GA
Clothing	Wear in simple, light, and comfortable styles. It can decrease the weight of luggage, thereby reducing energy consumption in transportation and subsequent washing/cleaning.	ST
Accommodation (Housing)	Stay in natural (e.g., green construction materials), energy-efficient and local hotel.	GB and GE
Traffic	Use low-carbon intensity vehicles (electric vehicles). Take public transport such as mass rapid transit (MRT) and bus; ride bikes; or walking.	GT, GE, and ST
Education	Be respectful to the nature. Introduce the concept of 6R, i.e., Redesign, Reduce, Reuse, Recycle, Recovery (energy), and Reclamation (land).	GI, GE, and ST
Entertainment	Experience the culture, and visit to community, farms and ecological sites such as wetland.	GA, GB, GI, and ST
Purchasing	Buying local products, e.g., cultural specialty, agricultural products and handicrafts.	GA and GT
Charity	Reduce individual carbon intensity by, for instance, purchasing carbon credits. Participate in environmentally friendly practices such as tree planting.	GA

^a GA (green agriculture); GB (green building); GE (green energy); GI (green infrastructure); GT (green transport); ST (smart technology).

4.2. Enhancement of institutional networks and public-private-people participation

Implementation strategies on sustainable tourism development require cross-sectoral linkages. It is especially imperative to address the institutional and structural challenges faced by tourism sectors. The effective operations of the tourism economy largely depend on the institutional arrangements and structural frameworks within the entire social economic system (Tang, 2017). To ensure wide participation and consensus building, development of sustainable tourism requires strong political leadership, as well as the informed participation of all relevant stakeholders (UNEP and UNWTO, 2005). Different stakeholders, such as governments (policy-makers), tourists, hosts (firms), practitioners, educators, and non-profit and for-profit organizations, should be involved in the development and implementation of sustainable tourism.

Synergies should be developed among institutional networks along with public-private-people participation (4P). Cooperation between international development institutions and the tourism industry also should be enhanced. Especially for developing countries, fostering the network in global ecotourism communities allow them to share success lessons and available green practices. These are essential steps to integrated sustainability into policies and management practices. It is noted that collaboration among stakeholders also can ensure the improvement of the tourism sector's performance on SCP.

According to the review on tourism planning models (Moscardo, 2011), although stakeholders are important, few research on detailed direction for identifying and engaging with stakeholders is provided. Waligo et al. (2015) employed the traffic light routes framework analogy for evaluate stakeholders' perceptions of sustainable tourism strategies and their impact on tourism initiatives. Similarly, Hardy and Pearson (2017) utilized the Q methodology (or Q-sort factor analysis) to assess the attitudes of stakeholders on sustainable tourism in Australia. The results reveal that, when considering sustainable tourism development, the attitudes of individual stakeholders do not always

align to their stakeholder group. Therefore, responsive methods are necessary to ensure adequate stakeholder involvement. Furthermore, Law et al. (2016) developed an integrated framework and model for translating the green economy system into a tourism stakeholder engagement process from a tourism perspective. This developed model has integrated several approaches including visioning group techniques, tourism economy and employment forecasting, resource efficiency estimates, and resident/visitor surveys.

4.3. Provision of adequate economic instruments

Sustainability for tourism business should ensure long-term profitability by reforming policy, institutional and regulatory conditions that govern business activity (UNWTO, 2017a), as well as through well-tempered price policies and diverse products (ETE, 2009). Practice guidelines and regulations should be proposed in accordance with national visions and legislation. For instance, promoting foreign direct investment (FDI) could effectively improve market awareness, economic stability, quality control, skill/knowledge levels, and technology transfer. It is noted that the FDI should be well-grounded in destinations, which maximizes economic benefits for local communities (UNWTO, 2017a). In addition to the FDI, provision of adequate economic instruments from government can enhance public investment and financing in sustainable tourism. Economic instruments, such incentives, eco-taxes and charges from tourists, can motivate private cooperates to change their operations toward sustainability, thereby ensuring sustainable practices in tourism businesses.

Incentives should influence the practice of tourism activities and development toward sustainability via changing the behavior or the business practice of tourism providers. Such incentive schemes comprise incorporation of fuel prices and taxes with externality across transport sectors, reduction in tourist taxes, or provision of discounted prices for tourists choosing environmentally friendly behaviors. In addition, the incentives should be administered in a way with adequate framework and transparency, as well as helping enable capacity building. Different types of incentives, including contests, awards, certification, labeling, grants, trademarks/umbrella brands and promotional actives, can be implemented. In most cases, incentives are only a first step or a component in the early stage of sustainable tourism development program. Since incentives alone cannot solve all concerned issues of tourism, the evaluation system should set comprehensive (i.e., clear, realistic and meaningful) indicators rather than too demanding and beyond capacity.

Fiscally supporting green practices, such as water-saving equipment and energy-efficient heating/cooling and lighting systems in buildings, can make substantial progress in sustainable tourism. Similarly, continuous investments in public green transport are fundamental to spearhead greater connectivity and reduce carbon footprints (UNWTO, 2017a). On the other hand, both public and private investments should help launch tourism projects with vulnerable communities (i.e., heritages and cultures) under an agreement on shared responsibilities. Investments in community development (e.g., early warning systems), environment protection (e.g., emergency response and recovery plans) and market diversification can secure resilience and social insurance, as well as mitigate the shocks of international market trends (UNWTO, 2017a).

4.4. Implementation of integrated management programs

To ensure the tourism development is environmentally, economically, socially and culturally sustainable, integrated management programs based on the principles of sustainability must be established. The integrated management program should be a proactive approach to the regulation of tourism in a specific area based on tourism management plans adopted by local authorities, and coupled with risk management plans. The framework of the integrated management programs for

a tourism industry should follow the PDCA (Plan-Do-Check-Action) principle, as shown in Fig. 4. It comprises four stages: (i) development of a management plan, (ii) its consequent implementation, (iii) performance evaluation and impact assessment, and (iv) feedback and response.

In the first stage, the proposal and planning should be related to the political background of a destination. Also, at an early stage of the planning process, the participation of local community and population is crucial for the success of the subsequent implementation and management of plans. It is noted that participation could include a wide range of elements, such as providing information, facilitating consultation, assisting coordination, initiating cooperation and making decision (ETE, 2009). Then the management plan should be implemented with appropriate supervision and compliance. In this stage, green practices and technology industries (such as IoT and ICT) should be incorporated. For instance, monitoring system must be established based on clear indicators, accurate and precision measures, analysis of carrying capacity, limits of acceptable change, and sound trouble-shooting mechanisms. In the third stage, the evaluation and assessment are expected to enrich the knowledge of sustainability strategies and integrated management for tourism activities. It should monitor the performance of tourism development, assess the impacts of existing tourism activities, and provide a prospect on future tourism development. The impact assessment in a protected region should be designed as a holistic approach to considering the ecology, environment, society, economy and culture. Commonly used assessment methods include social impact assessment, environmental impact assessment, and strategic environmental assessment. Finally, based on the results of evaluation and assessment, the feedback and response should be applied to revise or modify the proposed plans.

To ensure sustainable tourism outcomes, various methodological tools and models can be employed, such as land-use planning (Trirat et al., 2014), importance-performance analysis (IPA) (Boley et al., 2017), actor-network theory (ANT) based framework (Dedeke, 2017), computable general equilibrium model (Dwyer et al., 2016), economic tools and analysis (Torre and Scarborough, 2017) and experience-concept model (Eide et al., 2017). For land-use planning, Trirat et al. (2014) emerged the learning process during agricultural resource planning such as green mapping, resources' symbol making, and GPS coordinating, to enhance the participation of community. Regarding the stakeholder involvement, the IPA can identify gaps between the perceptions of stakeholders on the importance of a specific attribute and the performance of a tourism firm on managing the attribute. In the meantime, the ANT can be adopted as an important analytical framework for tourism research, especially the relationships between non-humans and humans.

4.5. Bridging smart technology industry with tourism sector

Recently, the concept of "smart tourism" has been proposed, which is defined as an individual tourist support system within the context of information and communication technology services. Different to traditional tourist information services, the smart tourism emphasizes the ubiquitous tour information service received by tourists during a touring process through initiatives based on the special requirements of those individuals (Li et al., 2017b). This requires the development and application of smart technology, such as IoT and ICT technologies. The ICT infrastructure is related to connectivity, market access, distribution and networking via internet. Great internet accessibility can bolster connectivity, marketing, distribution and networking, thereby underscoring the importance of developing and deploying the ICT infrastructure, particularly in developing countries or rural and remote regions. Moreover, the real-time monitoring system based on the WSNs should be installed to allow developing a sustainable and profitable system that can evaluate the relationship between the environment (in terms of natural environment or satisfaction of tourists) and a sustainable tourism.

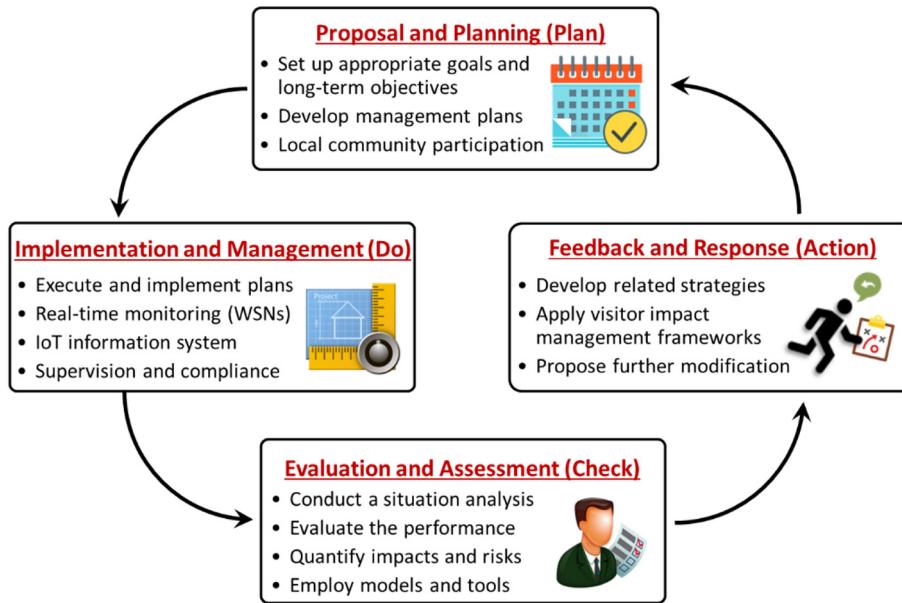


Fig. 4. Integrated management framework for tourism industry in accordance with PDCA principle.

In addition, effective marketing and the use of social media can significantly increase tourists' awareness of their own impacts on sustainability (UNWTO, 2017a). For instance, on-screen tourism (or film tourism) can greatly increase tourist arrivals to a certain place as a result of films or TV drama series. An important strategy in the promotion of on-screen tourism destinations is to create an iconic concept, for instance Middle Earth in the Hobbit (Li et al., 2017a). This should be effectively incorporated with marketing strategies and media convergence. Similarly, with the application of geographic information system, a "green" map with tourist attractions such as shop locations of local agri-food products should be provided to enhance the linkage of tourism and agriculture development.

4.6. Creation of cultural (heritage) responses and public awareness

Considering protection and maintenance of heritage while making use of tourism activity as a means of conservation is imperative of eco-tourism. In fact, tourism could provide great opportunities for continuation, enhancement and rejuvenation of traditions and lifestyles. The heritage and conservation issues should be involved in the mitigation and adaptation plans to climate change. Also, they must be conducted in close collaboration with relevant stakeholders. Tourists would wish to participate in recreation and to learn about natural and culture heritage of the places visited. Therefore, governments and tourism departments should consider the benefits of heritage and cultural industries, and thus develop the economic, political, and cultural function of sustainable tourism. This is the concept of heritage economy, which is a cross-disciplinary system, including three economic contexts: heritage economy, cultural economy and tourism economy. The cultural industry represents a basic demand and supply economic system. However, clear conceptual frameworks have not existed for most of heritage and culture tourism economies (Xu et al., 2017). In addition, both natural and cultural heritage is usually vulnerable to the effects of globalization, modern development and people lifestyles. It is noted that the physical and cultural impacts of tourism depend on the characteristics of the tourists (e.g., number and nature) and the site where tourism activities take place (ETE, 2009).

Ecotourism should ensure a high satisfaction and a meaningful experience to tourists to increase their awareness and consciousness about sustainable and green practices (UNEP and UNWTO, 2005). In fact, changing consumer/tourist patterns can provide promising

opportunities for promoting public awareness and achieving sustainable tourisms. Once publics become environmentally and socially conscious, people would look for a responsible alternative to traditional tourisms. Eagle et al. (2016) conducted a sophisticated multi-method research to develop insights into segmentation-based strategies and behaviors, which can successfully identify barriers and opportunities to sustained behavior change. In their study, the decision variables include pricing and innovation policies, emission caps and investments in infrastructure by governments and corporations. Furthermore, to provide credible measures of economic contribution by tourism, efforts should be focused on ensuring sustain and participatory data collection, conducting existing statistical frameworks, involving needs-based indicators for tourism management (UNWTO, 2017a). For instance, the marketing and advertising campaign should be carefully designed to intensify public awareness around the sustainable tourism policies and implementation (Dimitriou, 2017).

5. Establishment of comprehensive performance evaluation (CPE) programs

Sustainable tourism should balance economic benefits, environmental protection, social justice and cultural integrity to meet the needs of the host community and improve living standards (Liu et al., 2013). Along the way, the establishment of comprehensive performance evaluation (CPE) programs is regarded as an essential component for achieving sustainable tourism. In this section, the criteria, framework and methodology of establishing CPE programs are illustrated. A case study of the Green Island at Taiwan is also provided.

5.1. Criteria and framework

In general, a common language and organizing structure for effectively measuring the economic, environmental and social dimensions in tourism industry should be developed. However, current tourism measurement standards are largely economic (UNWTO, 2017b). Thus, the UNWTO, supported by the United Nations Statistics Division, has launched an initiative toward a 'Statistical Framework for Measuring Sustainable Tourism' (MST), as shown in Fig. 5. This proposed framework can provide a base to facilitate dialogue between different sectors, as well as to encourage integrated decision-making via exploiting the rich level of data already available. The set of performance indicators

should be carefully determined and adjusted according to the local conditions of the evaluated region. The measured figures of each indicator must be subject to adequate and qualified interpretation by independent panels and experts, such as an ad-hoc committee.

Key performance indicators (KPIs) are figures (tangible) or characteristics (intangible) that can represent the condition or the change of the state of a certain aspect. To adjust the importance of single KPI for one aspect, each KPI should be weighted to different degrees to adequately determine the state or the improvement of the aspect. Numerous effective methodologies, such as a Delphi method (Choi and Sirakaya, 2006), an analytical hierarchy process (Mikulić et al., 2015; Park and Yoon, 2011) and a fuzzy Delphi-analytical network process (Zhang, 2017), can be applied to assess the relative importance of sustainable tourism indicators. In contrast, the use of equal weighting system for sustainability KPIs to facilitate the interpretation of each indicator could also be considered (Singh et al., 2012).

5.2. Key performance indicators

KPIs can be derived using qualitative and/or quantitative approaches to elucidating complex realities. Singh et al. (2012) summarized various types of sustainability indices that can be practically implemented to measure the performance of sustainable development, such as innovation, knowledge, technology, development, market-based and composite sustainability performance indices. Similarly, Lee and Hsieh (2016) have identified 143 sustainability indicators for wetland tourism. Also, Votsi et al. (2014) suggest that both the conservation and acoustic quality of a site are important in environment-conscious tourism destinations, which might function as a tool for management or serve as a KPI. Addressing the social and cultural indicators would be more challenging because they often defy simple resolution and require industry- and community-wide involvement and commitment (Agyeiwaah et al., 2017). On behalf of enterprises, a corporate social responsibility report is a good option to reveal the social and cultural indicators in a meaningful manner.

5.3. Methodologies and tools

Various methodologies, such as material flow analysis, life cycle assessment, ecological footprint and risk assessment, can be tailored to quantify the KPIs and/or benchmarks for the subsequent decision-making procedure. Development of integrated models for comprehensive performance evaluation is of importance to balance economic growth and environmental protection toward sustainable tourism. These models can provide a general understanding of the types of

tradeoffs that might be expected when considering development of tourism in a natural location and the role for infrastructure in enhancing the carrying capacity for tourism in this area. Dvarskas (2017) has developed an integrated model linking tourists behavior with an ecological model to estimate the environmental impacts of the increased visitors. Hernández and León (2007) expanded a life-cycle model to quantify the interaction between natural and physical capital, such as the visitation and infrastructure investments related to environmental assets, depending upon the intensity of resource use.

Understanding the dynamic relationship among GHG emissions, economic growth, and tourism development is quite important for the government and policy makers. Paramati et al. (2017) conducted a comparative analysis on the tourism-CO₂ emissions nexus by modeling the influence of tourism development on economic growth and CO₂ emissions in the context of Eastern and Western EU. However, since such tools are seldom used during tourism development, there could be a risk of overlooking significant impacts or of shifting the responsibility onto upstream/downstream actors in the supply chain (Budeanu et al., 2016). Therefore, the uncertainty and/or sensitivity analysis should be conducted to identify the gaps and evaluate the robustness of KPIs. This can further enhance the transparency and credibility of the KPIs.

5.4. Case study: the Green Island at Taiwan

Green Island, with a land area of ~15.1 km², is a volcanic island in the Pacific Ocean about 33 km off the eastern coast of Taiwan. It was served as a penal colony for political criminals and prisoners during the period of martial law, and now it is known as a hotspot of ecotourism. In January 2010, the Taiwan Government initiated a low-carbon city program to promote the development of ecotourism on several demonstration islands, such as Green Island, for achieving the green economy. A cross-disciplinary perspective encompassing green energy, green transport, green building, circular economy, management information system, and education/training program was considered in the establishment of sustainable tourism at the Green Island. Fig. 6 illustrates the network of integrated sustainable infrastructures, including green energy, green building and lithium ion battery (LIB) charge station, for sustainable tourism at the Green Island. For instance, before the sustainable tourism program, the Green Island was powered by a diesel-fired power plant with a capacity of 29 MW, consisting of 28 units of generators. By this program, a total of six renewable energy facilities including solar PV and wind power has been installed on the Green Island. The average wind speed in the Green Island is about 5–7 m/s, which can be utilized to generate electricity via wind power facilities (especially for the E6 location). The green energy facilities are

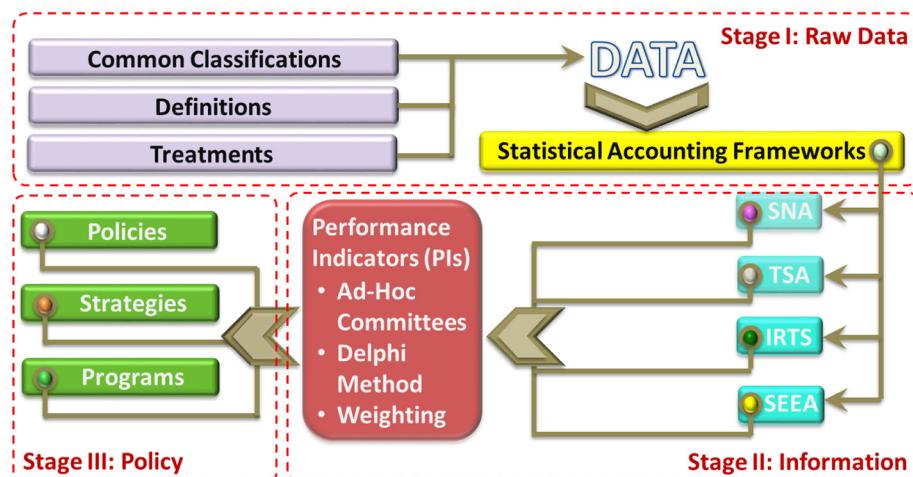


Fig. 5. Toward a statistical framework for measuring sustainable tourism. Acronyms: SNA (System of National Accounts); TSA (Tourism Satellite Account); IRTS (International Recommendations for Tourism Statistics); SEEA (System of Environmental Economic Accounting).

also connected with green buildings at several key tourism attractions, such as the Green Island prison (E2/B2) and tourist center (E3/B3).

In addition to the development of sustainable infrastructures, a KPI system for evaluating the performance of the sustainable tourism at the Green Island was established, as shown in Fig. 7. The KPI system comprised three stages to break down the original 26 performance indicators to ten KPIs via an Ad Hoc committee. This KPI system was incorporated with the scopes of the National Sustainable Development Policies, as well as the principles of low-carbon community and green infrastructure. In particular, implementation of green practices on sustainable tourism activity, such as renewable energy, trash reduction, green transport, and environmental education, was emphasized. These KPIs are closely related to the six cross-disciplinary components as indicated in Section 3 of this study. They also could be served as a basis for governments and enterprises to develop their own specific metrics according to their goals, measure current status, and assess relevant progress toward achieving sustainable tourism.

6. Perspectives and prospects

While tourism exhibits a great positive contribution on economic development, it is often blamed for environmental quality degradation and natural resource depletion through anthropogenic activities and improper management. In this section, perspectives and prospects on sustainable tourism, including green economy, circular economy, transformative power of sustainability, and water-energy-food nexus, are illustrated.

6.1. Transition to a green economy from tourism business approaches

The movement of tourism industry toward sustainability implies significant changes in the modes of conventional tourism. For instance, it should involve growth and improvements in niche areas focused on natural, cultural and social resources. There is a trade-off between the monetary benefits accruing from economic activities (e.g., tax revenues and employment) and ecosystem-service benefits (e.g., wildlife and clean water for recreation). In other words, the essential targets of improvement should include the economic (e.g., net tourism revenues), environment (e.g., biodiversity), and social (e.g., access to tourism) aspects. Fig. 8 illustrates a green economy model incorporated with integrated sustainable infrastructures for ecotourism development. The contribution of tourism sectors to the SDGs should be evaluated from a multidisciplinary approach to simultaneously addressing climate change and other priorities such as poverty alleviation and a green economy. It is also imperative to integrate SCP patterns in tourism related policies and frameworks. By making tourism businesses more sustainable, it could provide green growth, create green jobs, increase benefits to local communities, and raise public awareness to support SCP patterns. Tourism can provide another source of income in developing countries because it effectively transfers income from developed to developing economies. The aforementioned considerations are entirely related to the transition to a green economy system.

A successful transition of tourism to a green economy requires sound policies and strategies, as well as specific local conditions (e.g., regulation, institution, technology and financial) for success. From a business perspective, re-structuring the tourism system toward

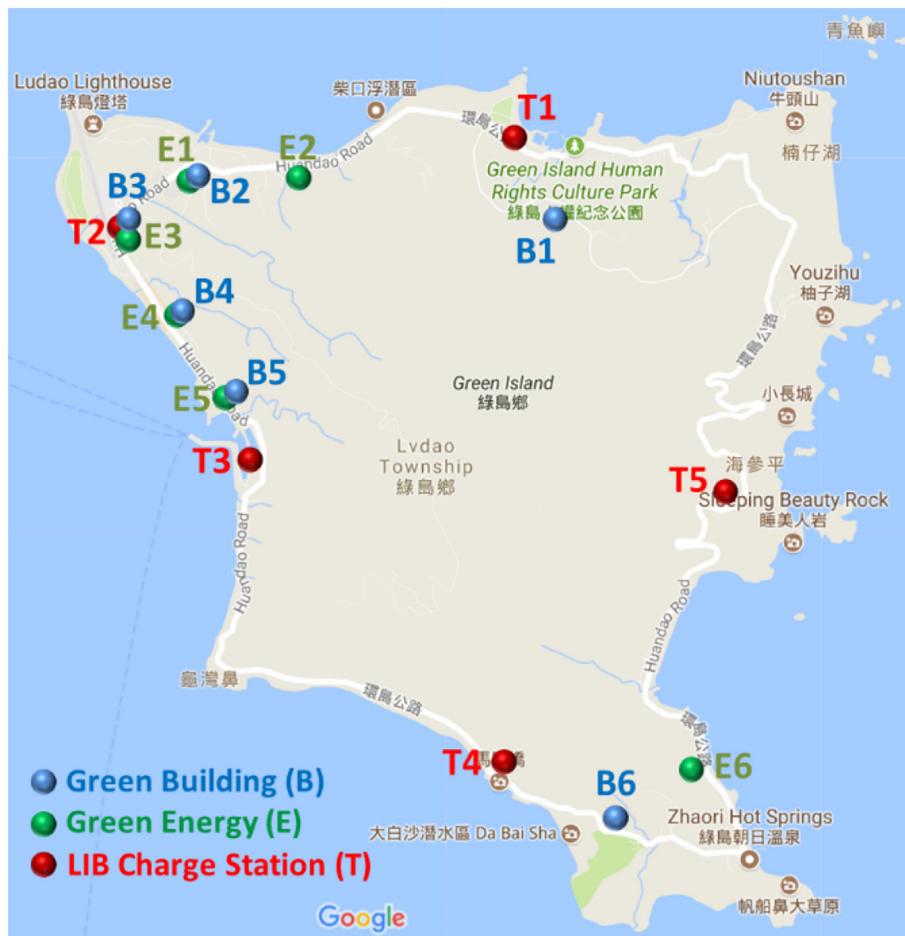


Fig. 6. Network of integrated sustainable infrastructures for sustainable tourism on Green Island. Acronym: LIB: lithium ion battery. Screenshot of the Google Map taken by the authors. This figure is licensed under a CC-BY Creative Commons Attribution 4.0 International License. Google and the Google logo are registered trademarks of Google Inc., used with permission.

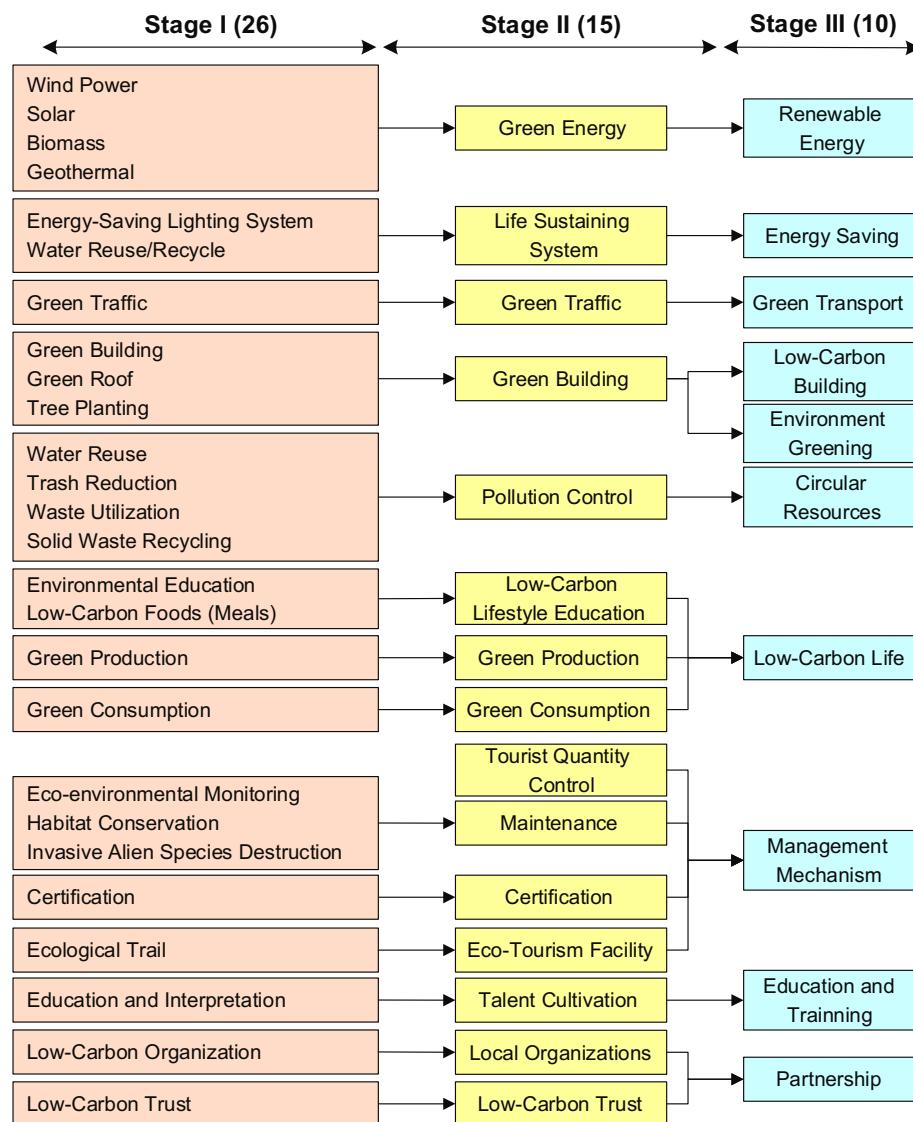


Fig. 7. Determination of key performance indicators for establishing CPE programs of sustainable tourism on the Green Island.

low-carbon consumption must achieve the concept of eco-efficiency, which combines two factors: (i) lowering GHG intensity of tourism products and (ii) increasing profit margins. The term eco-efficiency represents the amount of energy used or pollution emitted to support one unit of a given currency. Tourism sector should capitalize on the vast opportunities to combine emission reductions and economic revenues, where involvement and engagement of tourism stakeholders are the priorities to achieve a green economy. Furthermore, the tourism sector should actively engage in the market of carbon offsets, and participate in a variety of carbon standards and certification schemes, such as clean development mechanism, social carbon, green e-climate, gold standard, and verified carbon standard. Carbon off-setting in tourism sectors could be an opportunity for developing countries to increase their economic revenues. The aforementioned elements can provide critical transition to a green economy.

6.2. Sustainable materials management (SMM) for a circular economy

Sustainable tourism plays an important role in accelerating green economic growth, and also provides great opportunities for achieving a CES. To effectively establish the CES, the concept of SMM should be applied in tourism industry to use and reuse materials (e.g., wastewater and residues) more productively over their entire lifecycles. SMM is a

systematic approach to sustainably managing materials and products throughout the entire life-cycle, e.g., from resource extraction, manufacturing and consumption to end-of-life management. Opportunities for “greening” the tourism sector are not only environmentally sound, they also promise substantial businesses savings through efficient resource management and sourcing local supplies, materials and services. To accelerate the transition to a circular economy, an economy that is restorative and regenerative by design for keeping resources at the highest use and value throughout their life cycle should be developed. However, to spearhead the efficient use of natural resources under the SMM framework, there is still a need for holistic planning, strict impact assessments, and effective management in water-energy-food nexus (particularly in regions of water scarcity). Good practices of retrofitting existing structures, including improvement of building insulation, replacement of fossil-fuel based equipment, and deployment of renewable energy, should be supported.

6.3. Connection to water-energy-food (WEF) nexus

Population growth, increased energy and food needs, and economic development exert increasing pressures on natural resources. Water, energy and food (WEF) nexus is a critical issue to be considered in future development of tourism sector, such as mitigation and adaptation

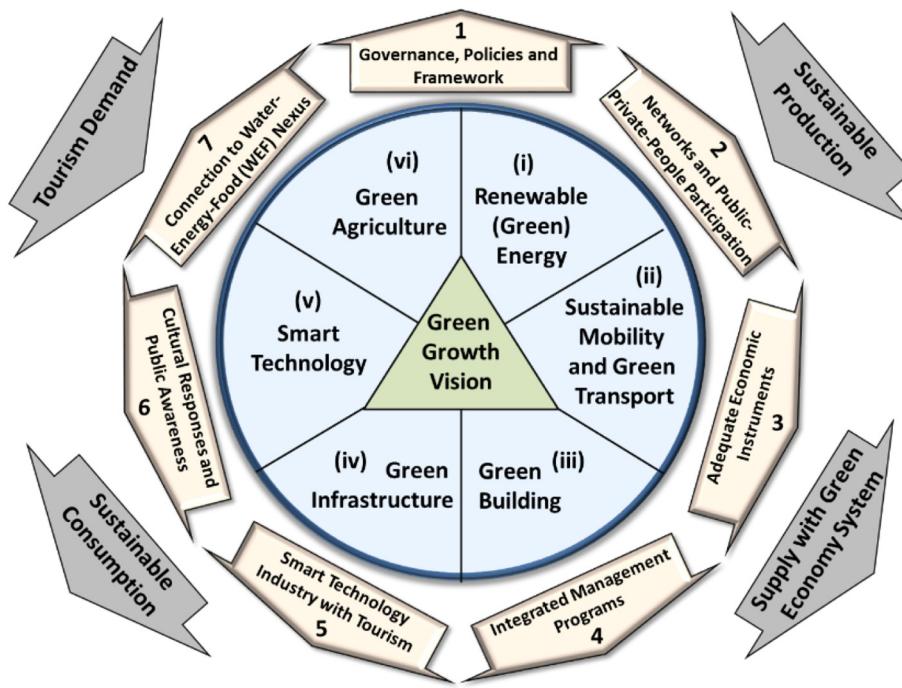


Fig. 8. Green economy model incorporated with integrated sustainable infrastructures for ecotourism development.

strategies, and GHG emission calculations. Since the nexus term in the context of water, energy and food (agriculture) implies these sectors being inextricably related, tourism activities commonly have impacts on the others, as well as on the environment and ecosystems. Aside from the nexus between water and energy (as aforementioned in Sections 2–3), for instance, tourist development is increasingly competing for water with the agricultural sector (nexus between water and food). Due to the overuse of renewable water supplies (e.g., underground water) and altered precipitation patterns caused by climate change, water resources will decrease in many countries. Especially in small developing islands, the decrease in available water resources will certainly affect tourism activities. Similarly, in the case of small isolated islands or peripheral tourism destinations, food (agricultural products) would be imported over greater distances, resulting great impacts on global climate change and local economic development. On the other hand, the amount of energy to produce food can be significant (nexus between energy and food). These high costs could make tourism business less profitable. Therefore, as the costs of energy and food continue to rise, tourism sectors can resort producing their own food (e.g., agritourism) or making more green options to achieve the sustainability (Randle and Halter, 2013).

An inter-sectoral approach to managing the interlinked resources can enhance water, energy and food security by increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors. In other words, sustainable tourism should be incorporated with the concept of green energy supply, sustainable water management, and green agriculture to address the WEF nexus for better informing decision-making regarding sustainable development. Furthermore, research on links between sustainable tourism and the impact of population growth is still limited. At the global scale, population growth keeps increasing the intensity of tourism activities and its impacts (Buckley, 2012). However, there is little evidence whether tourism influences population, which should be one of the key focuses in the future research.

6.4. Summary

Tourism industry is a dynamic system, where transformative change depends on numerous factors such as the cultural adaptability of

various actors involved. Rather simply one type of tourism, sustainable tourism represents a broad range of cross-disciplinary principles that can be applied across the whole tourism sector. For instance, these sustainability principles could include (i) optimization of water-energy-food nexus, such as increasing use of renewable energy and consuming less water, (ii) establishment of circular economy, such as minimizing waste and converting wastes into valuable products, (iii) protection of environment and ecological spheres, such as using biodegradable products for guests and conserving biodiversity, (iv) creation of culture values, such as conserving cultural heritage and traditional values, and supporting intercultural understanding and tolerance, and (v) greening tourism business, such as generating local income, integrating local communities with a view to improving livelihoods and reducing poverty, and enabling tourism businesses to make long term investments.

7. Conclusions

The transformation of tourism toward sustainability and a green economy demands a cross-disciplinary approach to implementation, such as integrative (international, national and local) policies, investments in innovative technologies, strong partnerships between governments and tourism firms, and promotion of green practices (e.g., efficient use of energy and water, and integrated waste management). Incorporation with environmental education to enhance public awareness also would facilitate the transformation. One of the future research on sustainable tourism should focus on assessment of policy and sector investment measures and feedback systems that control corporate and tourist behaviors by using generalized rules. Regarding the innovative technologies for tourism, hybrid renewable energy system, i.e., combining two or more renewable energy sources that work in standalone or grid connected mode, should be considered. This should be incorporated with the modeling, analysis, control and management strategies for implementation and optimization of renewable energy. The renewable energy system also can be linked to the development of public transport system. To achieve the sustainable mobility for tourism, it is imperative to upgrade the existing public transportation and introduce green vehicles such as electric or hybrid cars. Also, a carbon tax could be imposed on self-drive tourists to ensure energetic development of the green public transport system. On the other hand, the smart

technology, such as WSNs and IoT, have promisingly provided great opportunities for the rapid development of renewable energy, public transport and tourism activity. It also changed the vision of scientists studying the earth and environmental sciences, where they will face the evaluation of huge amounts of data collected (i.e., big data analysis). This would speed up the transformation of an integrated approach to developing innovative methods and applying new advanced solutions to scientific problems.

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References

- Aall, C., 2014. Sustainable tourism in practice: promoting or perverting the quest for a sustainable development? *Sustain. For.* 6, 2562–2583.
- Agyeiwaah, E., McKercher, B., Suntikul, W., 2017. Identifying core indicators of sustainable tourism: a path forward? *Tour. Manag. Perspect.* 24, 26–33.
- Álvarez-Albelo, C.D., Hernández-Martín, R., Padrón-Fumero, N., 2017. Air passenger duties as strategic tourism taxation. *Tour. Manag.* 60, 442–453.
- Angelstam, P., Khaulyak, O., Yamelynets, T., Mozgeris, G., Naumov, V., Chmielewski, T.J., et al., 2017. Green infrastructure development at European Union's eastern border: effects of road infrastructure and forest habitat loss. *J. Environ. Manag.* 193, 300–311.
- Asiedu, A.B., Gbedema, T.K., 2011. The nexus between agriculture and tourism in Ghana: a case of unexploited development potential. In: Torres, R.M., Momsen, J.H. (Eds.), *Tourism and Agriculture: New Geographies of Consumption, Production and Rural Restructuring*. Routledge, New York, pp. 28–46.
- Ballantyne, R., Packer, J., 2013. *International Handbook on Ecotourism*. Edward Elgar Publishing.
- Beccali, M., La Gennusa, M., Lo Coco, L., Rizzo, G., 2009. An empirical approach for ranking environmental and energy saving measures in the hotel sector. *Renew. Energy* 34, 82–90.
- Becken, S., Hay, J., 2007. *Tourism and Climate Change – Risks and Opportunities*. Channel View Publications, Cleveland.
- Boley, B.B., McGehee, N.G., Tom Hammett, A.L., 2017. Importance-performance analysis (IPA) of sustainable tourism initiatives: the resident perspective. *Tour. Manag.* 58, 66–77.
- Bows, A., Anderson, B., Peeters, P.M., 2009. Air transport, climate change and tourism. *Tour. Hosp. Plann. Develop.* 6, 7–20.
- Bramwell, B., Lane, B., 2012. Towards innovation in sustainable tourism research? *J. Sustain. Tour.* 20, 1–7.
- Buckley, R., 2011. *Tour. Environ. Annu. Rev. Environ. Resour.* 36, 397–416.
- Buckley, R., 2012. Sustainable tourism: research and reality. *Ann. Tour. Res.* 39, 528–546.
- Budeanu, A., Miller, G., Moscardo, G., Ooi, C.-S., 2016. Sustainable tourism, progress, challenges and opportunities: an introduction. *J. Clean. Prod.* 111, 285–294.
- Cama, A., Montoya, F.G., Gómez, J., De La Cruz, J.L., Manzano-Agugliaro, F., 2013. Integration of communication technologies in sensor networks to monitor the Amazon environment. *J. Clean. Prod.* 59, 32–42.
- Choi, H.C., Sirakaya, E., 2006. Sustainability indicators for managing community tourism. *Tour. Manag.* 27, 1274–1289.
- D'Alessandro, F., 2016. Green building for a green tourism. A new model of eco-friendly agritourism. *Agricul. Agricul. Sci. Proc.* 8, 201–210.
- Dedeke, A., 2017. Creating sustainable tourism ventures in protected areas: an actor-network theory analysis. *Tour. Manag.* 61, 161–172.
- Díaz, J.A.R., Knox, J.W., Weatherhead, E.K., 2007. Competing demands for irrigation water: golf and agriculture in Spain. *Irrig. Drain.* 56, 541–549.
- Dimitriou, C.K., 2017. The quest for a practical approach to morality and the tourism industry. *J. Hosp. Tour. Manag.* 31, 45–51.
- Dvarskas, A., 2017. Dynamically linking economic models to ecological condition for coastal zone management: application to sustainable tourism planning. *J. Environ. Manag.* 188, 163–172.
- Dwyer, L., Forsyth, P., Spurr, R., 2016. Tourism economics and policy analysis: contributions and legacy of the Sustainable Tourism Cooperative Research centre. *J. Hosp. Tour. Manag.* 26, 91–99.
- Eagle, L., Hamann, M., Low, D.R., 2016. The role of social marketing, marine turtles and sustainable tourism in reducing plastic pollution. *Mar. Pollut. Bull.* 107, 324–332.
- Eide, D., Fuglsang, L., Sundbo, J., 2017. Management challenges with the maintenance of tourism experience concept innovations: toward a new research agenda. *Tour. Manag.* 63, 452–463.
- ETE, 2009. *Sustainable Tourism Development in UNESCO Designated Sites in South-Eastern Europe. Ecological Tourism in Europe (ETE)*, Bonn, Germany, p. 43.
- Forsyth, P., Dwyer, L., Spurr, R., Pham, T., 2014. The impacts of Australia's departure tax: tourism versus the economy? *Tour. Manag.* 40, 126–136.
- Fuqiang, W., Ziming, C., Jianyu, T., Yuan, Y., Yong, S., Linhua, L., 2017. Progress in concentrated solar power technology with parabolic trough collector system: a comprehensive review. *Renew. Sust. Energ. Rev.* 79, 1314–1328.
- Gasparatos, A., Doll, C.N.H., Esteban, M., Ahmed, A., Olango, T.A., 2017. Renewable energy and biodiversity: implications for transitioning to a green economy. *Renew. Sust. Energ. Rev.* 70, 161–184.
- Germann Molz, J., Paris, C., 2013. The social affordances of flashpacking: exploring the mobility nexus of travel and communication. *Mobilities* 10, 173–192.
- Gössling, S., 2001. The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania. *J. Environ. Manag.* 61, 179–191.
- Gössling, S., 2005. Tourism's contribution to global environmental change: space, energy, disease and water. In: Hall, C.M., Higham, J. (Eds.), *Tourism Recreation and Climate Change: International Perspectives*. Channel View Publications, Clevedon.
- Gössling, S., 2010. *Carbon Management in Tourism: Mitigating the Impacts on Climate Change*. Routledge, London.
- Green Nylen, N., Kiparsky, M., 2015. *Accelerating Cost-effective Green Stormwater Infrastructure: Learning from Local Implementation*. U.C. Berkeley School of Law: Center for Law, Energy & the Environment.
- Hall, C.M., 2010. Changing paradigms and global change: from sustainable to steady-state tourism. *Tour. Recreat. Res.* 35, 131–143.
- Hannam, K., Butler, G., Paris, C.M., 2014. Developments and key issues in tourism mobilities. *Ann. Tour. Res.* 44, 171–185.
- Hardy, A., Pearson, L.J., 2017. Examining stakeholder group specificity: an innovative sustainable tourism approach. *J. Destination Market. Manage.* <https://doi.org/10.1016/j.jdm.2017.05.001> (in press).
- Hashemkhani Zolfani, S., Sedaghat, M., Maknoon, R., Zavadskas, E.K., 2015. Sustainable tourism: a comprehensive literature review on frameworks and applications. *Econ. Res.–Ekonomika Istraživanja* 28, 1–30.
- Hernández, J.M., León, C.J., 2007. The interactions between natural and physical capitals in the tourist lifecycle model. *Ecol. Econ.* 62, 184–193.
- Honeck, D., 2012. *LDC Export Diversification, Employment Generation and the "Green Economy": What Roles for Tourism Linkages?* World Trade Organization Economic Research and Statistics Division
- Hüller, S., Heiny, J., Leonhäuser, I.U., 2017. Linking agricultural food production and rural tourism in the Kazbegi district – a qualitative study. *Ann. Agrarian Sci.* 15, 40–48.
- IPCC. *IPCC Fourth Assessment Report (AR4)*, M., M., Z, C., M., K., B.A., et al., 2007. *Climate change*. In: Solomon, S., D., Q. (Eds.), *The Physical Science Basis. Intergovernmental Panel on Climate Change*. Cambridge, p. 2007.
- Kim, J.-Y., Hlee, S., Joun, Y., 2016. Green practices of the hotel industry: analysis through the windows of smart tourism system. *Int. J. Inf. Manag.* 36, 1340–1349.
- Kooahkan, P., Altieri, M.A., Gimenez, E.H., 2012. Green agriculture: foundations for biodiverse, resilient and productive agricultural systems. *Int. J. Agric. Sustain.* 10, 61–75.
- Law, A., De Lacy, T., Lipman, G., Jiang, M., 2016. Transitioning to a green economy: the case of tourism in Bali, Indonesia. *J. Clean. Prod.* 111, 295–305.
- Lee, T.H., Hsieh, H.-P., 2016. Indicators of sustainable tourism: a case study from a Taiwan's wetland. *Ecol. Indic.* 67, 779–787.
- Leung, D., Law, R., van Hoof, H., Buhalis, D., 2013. Social media in tourism and hospitality: a literature review. *J. Travel Tour. Mark.* 30, 3–22.
- Li, S., Li, H., Song, H., Lundberg, C., Shen, S., 2017a. The economic impact of on-screen tourism: the case of The Lord of the Rings and the Hobbit. *Tour. Manag.* 60, 177–187.
- Li, Y., Hu, C., Huang, C., Duan, L., 2017b. The concept of smart tourism in the context of tourism information services. *Tour. Manag.* 58, 293–300.
- Light, D., 2017. Progress in dark tourism and thanatourism research: an uneasy relationship with heritage tourism. *Tour. Manag.* 61, 275–301.
- Lim, C., McAleer, M., 2005. Ecologically sustainable tourism management. *Environ. Model Softw.* 20, 1431–1438.
- Liu, C.H., Tzeng, G.H., Lee, P.Y., 2013. Improving metro-airport connection service for tourism development: using hybrid MCDM models. *Tour. Manage. Perspect.* 6, 95–107.
- Mao, Y.H., Yang, G.H., 2011. Sustainable development drivers for green buildings: incremental costs-benefits analysis of green buildings. *Adv. Mater. Res.* 374–377, 76–81.
- Mihalic, T., 2016. Sustainable-responsible tourism discourse – towards 'responsustable' tourism. *J. Clean. Prod.* 111, 461–470.
- Mikulić, J., Kožić, I., Krešić, D., 2015. Weighting indicators of tourism sustainability: a critical note. *Ecol. Indic.* 48, 312–314.
- Moscardo, G., 2011. Exploring social representations of tourism planning: issues for governance. *J. Sustain. Tour.* 19, 423–436.
- Moscardo, G., 2016. Building excellence in sustainable tourism: 15 years of building excellence in sustainable tourism education network (BEST EN) practice. *J. Clean. Prod.* 111, 538–539.
- Newson, D., Dowling, R.K., 2010. *Geotourism: The Tourism of Geology and Landscape*. Godfellow Publishers Limited, Oxford, UK.
- Novas, N., Gázquez, J.A., MacLennan, J., García, R.M., Fernández-Ros, M., Manzano-Agugliaro, F., 2017. A real-time underground environment monitoring system for sustainable tourism of caves. *J. Clean. Prod.* 142, 2707–2721.
- Pan, S.-Y., Du, M.A., Huang, I.T., Liu, I.H., Chang, E.E., Chiang, P.-C., 2015. Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. *J. Clean. Prod.* 108, 409–421.
- Paramati, S.R., Shahbaz, M., Alam, M.S., 2017. Does tourism degrade environmental quality? A comparative study of Eastern and Western European Union. *Transp. Res. Part D: Transp. Environ.* 50, 1–13.
- Park, D.-B., Yoon, Y.-S., 2009. Segmentation by motivation in rural tourism: a Korean case study. *Tour. Manag.* 30, 99–108.
- Park, D.-B., Yoon, Y.-S., 2011. Developing sustainable rural tourism evaluation indicators. *Int. J. Tour. Res.* 13, 401–415.

- Peeters, P., Dubois, G., 2010. Tourism travel under climate change mitigation constraints. *J. Transp. Geogr.* 18, 447–457.
- Peeters, P., Szimba, E., Duijnisveld, M., 2007. Major environmental impacts of European tourist transport. *J. Transp. Geogr.* 15, 83–93.
- Polat, N., Hermans, E., 2016. A model proposed for sustainable accessible tourism (SAT). *Tékhne* 14, 125–133.
- Randle, D., Halter, R., 2013. Food choices are a key strategy for sustainable tourism. *Huffpost*. 2017. Oath Inc.
- Rizzo, A., 2017. Managing the energy transition in a tourism-driven economy: the case of Malta. *Sustain. Cities Soc.* 33, 126–133.
- Saarinen, J., Rogerson, C.M., 2013. Tourism and the millennium development goals: perspectives beyond 2015. *Tour. Geogr.* 16, 23–30.
- Sanchez-Pereira, A., Onguglo, B., Pacini, H., Gómez, M.F., Coelho, S.T., Muwanga, M.K., 2017. Fostering local sustainable development in Tanzania by enhancing linkages between tourism and small-scale agriculture. *J. Clean. Prod.* 162, 1567–1581.
- Scope ACP, 2011. Opportunities of Ecotourism in Promoting Land Management in the Caribbean. The Global Mechanism. United Nations Convention to Combat Desertification.
- Seetaram, N., Song, H., Page, S.J., 2014. Air passenger duty and outbound tourism demand from the United Kingdom. *J. Travel Res.* 53, 476–487.
- Serra-Llobet, A., Hermida, M.A., 2017. Opportunities for green infrastructure under Ecuador's new legal framework. *Landscape Urban Plan.* 159, 1–4.
- Setyaningsih, W., Iswati, T.Y., SriYuliani, Nuryanti, W., Prayitno, B., Sarwadi, A., 2015. Low-impact-development as an implementation of the eco-green-tourism concept to develop Kampung towards sustainable city. *Proc. Soc. Behav. Sci.* 179, 109–117.
- Sharpley, R., 2000. Tourism and sustainable development: exploring the theoretical divide. *J. Sustain. Tour.* 8, 1–19.
- Shih, Y.-H., Shi, N.-X., Tseng, C.-H., Pan, S.-Y., Chiang, P.-C., 2016. Socioeconomic costs of replacing nuclear power with fossil and renewable energy in Taiwan. *Energy* 114, 369–381.
- Si, J., Marjanovic-Halburd, L., Nasiri, F., Bell, S., 2016. Assessment of building-integrated green technologies: a review and case study on applications of multi-criteria decision making (MCDM) method. *Sustain. Cities Soc.* 27, 106–115.
- Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2012. An overview of sustainability assessment methodologies. *Ecol. Indic.* 15, 281–299.
- Su, B., Heshmati, A., Geng, Y., Yu, X., 2013. A review of the circular economy in China: moving from rhetoric to implementation. *J. Clean. Prod.* 42, 215–227.
- Tang, X., 2017. The historical evolution of China's tourism development policies (1949–2013) – a quantitative research approach. *Tour. Manag.* 58, 259–269.
- Thilakaratne, R., Lew, V., 2011. Is LEED leading Asia?: an analysis of global adaptation and trends. *Process. Eng.* 21, 1136–1144.
- Torre, A., Scarborough, H., 2017. Reconsidering the estimation of the economic impact of cultural tourism. *Tour. Manag.* 59, 621–629.
- Trave, C., Brunschweiler, J., Sheaves, M., Diedrich, A., Barnett, A., 2017. Are we killing them with kindness? Evaluation of sustainable marine wildlife tourism. *Biol. Conserv.* 209, 211–222.
- Trirat, S.S.-U., Poung-ngamchuen, J., Ponghan, S., Dangsuvann, M., Ponghan, K., 2014. Green map: agricultural resources management tool for community-based tourism. *APCBEE Proc.* 8, 248–253.
- Trung, D.N., Kumar, S., 2005. Resource use and waste management in Vietnam hotel industry. *J. Clean. Prod.* 13, 109–116.
- TTF, 2012. TTF submission to the senate legal and constitutional affairs committee. *Tourism & Transport Forum*. Parliament House, Canberra.
- UNEP, 2002. International Year of Ecotourism. United Nations Environment Programme, Paris.
- UNEP, 2003. A Manual for Water and Waste Management: What the Tourism Industry Can do to Improve its Performance. Division of Technology, Industry and Economics, United Nations Environment Programme, Paris.
- UNEP, 2006. GPA. The State of the Marine Environment - Trends and Processes. UNEP/GPA Coordination Office, p. 28.
- UNEP, 2013. Tourism Green Economy and Trade: Trends, Challenges and Opportunities. United Nations Environment Programme, pp. 260–291.
- UNEP and UNWTO, 2005. Making tourism more sustainable. A Guide for Policy Makers. United Nations Environment Programme and World Tourism Organization, Paris and Madrid.
- UNEP and UNWTO, 2012. Tourism in the Green Economy: Background Report. United Nations Environment Programme (UNEP) and World Tourism Organization (UNWTO), Spain and Kenya, p. 167.
- United Nations General Assembly, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations, New York.
- UNWTO, 2002. The British Ecotourism Market. World Tourism Organisation.
- UNWTO, 2010. Tourism and Biodiversity: Achieving Common Goals towards Sustainability. World Tourism Organization, Madrid.
- UNWTO, 2012. Message by the UNWTO Secretary-General, Taleb Rifai. World Tourism Organisation.
- UNWTO, 2016. A Roadmap for Celebrating Together. World Tourism Organization, Madrid, Spain, p. 20.
- UNWTO, 2017a. Discussion Paper on the Occasion of the International Year of Sustainable Tourism for Development 2017. United Nations World Tourism Organization, Madrid, Spain, p. 84.
- UNWTO, 2017b. UNWTO Annual Report 2016. World Tourism Organization, Madrid, Spain.
- UNWTO, UNEP, WMO, 2008. Climate change and tourism. Responding to Global Challenges. World Tourism Organization, United Nations Environment Programme and World Meteorological Organization, Paris and Madrid.
- Varma, K., Chaurasia, M., Shukla, P., Ahmed, T., 2014. Green building architecture: a literature review on designing techniques. *Int. J. Sci. Res. Publications* 4, 1–2.
- Viljoen, W., 2011. Aid for trade and the green economy in Africa. Bridges Trade BioRes Review. Vol. 5. International Centre for Trade and Sustainable Development, Switzerland.
- Votsi, N.-E.P., Mazaris, A.D., Kallimanis, A.S., Pantis, J.D., 2014. Natural quiet: an additional feature reflecting green tourism development in conservation areas of Greece. *Tour. Manage. Perspect.* 11, 10–17.
- Waligo, V., Clarke, J., Hawkins, R., 2015. Embedding stakeholders in sustainable tourism strategies. *Ann. Tour. Res.* 55, 90–93.
- WEF, 2009. Towards a Low Carbon Travel & Tourism Sector. World Economic Forum, Within the Framework of the Aviation, Travel & Tourism Partnership Programme.
- Weir, B., 2017. Climate change and tourism – are we forgetting lessons from the past? *J. Hosp. Tour. Manag.* 32, 108–114.
- Xu, S., Liu, Y., Qian, Y., Wang, Q., 2017. The significance of the West Lake pattern and its heuristic implications for creating China's heritage tourism economics. *Tour. Manag.* 58, 286–292.
- Xue, G., Hassanein, H., 2006. On current areas of interest in wireless sensor networks designs. *Comput. Commun.* 29, 409–412.
- Yovcheva, Z., Buhalis, D., Gatzidis, C., 2012. Overview of smartphone augmented reality applications for tourism. *e-Rev. Tour. Res.* 10, 63–66.
- Zhang, J., 2017. Evaluating regional low-carbon tourism strategies using the fuzzy Delphi-analytic network process approach. *J. Clean. Prod.* 141, 409–419.



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