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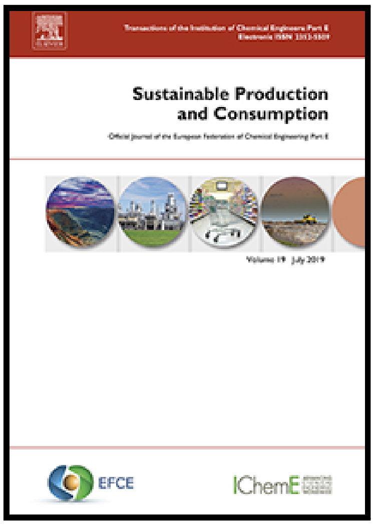

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Strategies to improve energy and carbon efficiency of luxury hotels in Iran

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Abstract

Luxury hotels generate substantial carbon footprint and scholarly research is urgently required to better understand how it could be effectively mitigated. This study adopts a method of life cycle energy analysis (LCEA) to assess the energy and carbon performance of six luxury, five star, hotels located in Iran. The results of the energy and carbon assessment of luxury hotels in Iran are compared against the energy and carbon values reported in past hotel research. This current study finds that luxury hotels in Iran are up to 3-4 times more energy- and 7 times more carbon-intense than similar hotels examined in past research. Low cost of fossil fuels, international trade sanctions and the lack of governmental and corporate energy conservation targets discourage Iranian hoteliers from carbon footprint mitigation. To counteract poor energy and carbon efficiency of luxury hotels in Iran, it is important to relax economic sanctions, develop alternative energy sources, refine corporate energy conservation targets, regularly benchmark hotel energy performance and enable exchange of good practices among Iranian hoteliers.

Keywords

Tourist accommodation

Energy consumption

GHG emissions

Carbon mitigation

Middle East

1. Introduction

Hotels consume excessive amounts of energy and, consequently, make a substantial contribution to climate change (Warren and Becken 2017). This is attributed to the continued growth of international tourism which generates circa 8% of global greenhouse gas (GHG) emissions (Lenzen *et al.* 2018). Currently, hotels hold a share of 21% in this carbon footprint (WTO and ITF 2019) but it is projected that, until 2035, it will increase to 25% (De Grosbois and Fennell 2011).

The need to reduce the contribution of hotels to global carbon footprint and decrease their share in the GHG emissions of international tourism has been repeatedly called for (Teng *et al.* 2012). Scholarly research is gradually responding to this call by exploring the causes and effects of GHG emissions in hotels and examining approaches to mitigation (Michailidou *et al.* 2015). Despite growing academic interest, a number of shortfalls exist in an understanding of the carbon footprint of hotels (Koiwanit and Filimonau 2021).

First, there is no single, universal method to appraise the GHG emissions of hotel operations (Filimonau 2016). Not only does this hinder a cross-boundary and cross-sectoral comparison of the carbon performance of hotels, but also affects accuracy of carbon footprint estimates (Schianetz *et al.* 2007). This is a major shortcoming as a basic principle of business management suggests that 'if one cannot measure [something] accurately, one cannot manage it [effectively]' (Elimelech *et al.* 2018). It has therefore become ever important to identify the most cost-effective methods of carbon footprint assessment capable to accurately appraise the GHG emissions of hotels (De Grosbois and Fennell 2011). It has become equally important to test/validate the practical viability of these methods, using hotels from different consumption markets and accommodation types as empirical case studies (Filimonau *et al.* 2011b). Validation is however problematic as hotel's administrations do not always collaborate with scholars on such sensitive topics as environmental and/or energy management (Filimonau and Krivcova 2017). Substantial difficulties are reported by academics when attempting to access hotel premises for primary data collection and/or when requesting hotel managers to provide data on energy performance (Lai *et al.* 2012; Oluseyi *et al.* 2016). This is partially because energy use data are often considered confidential with resultant managerial reluctance to share these with scholars (Filimonau *et al.* 2011a).

Second, extant research on the carbon footprint of hotels has limited geographical coverage. Studies have assessed the GHG emissions of hotels in Europe (Puig *et al.* 2017), North America (Kelly and Williams 2007), Australia and Oceania (Becken *et al.* 2001), East Asia (Teng *et al.* 2012), South East Asia (Trung and Kumar 2005) and South Asia (Singh *et al.* 2014), but there remains a paucity of studies in South America, Africa and the Middle East (Warren and Becken 2016). This is a major omission as tourism is set to grow in these geographies (UNWTO 2019) which will accelerate the carbon footprint of hotels. To make tourism in these regions and in specific countries within these regions more climate-benign, future research should aim at accurately assessing the GHG emissions of hotels and then designing appropriate mitigation strategies.

This paper contributes to knowledge by assessing the carbon footprint of six luxury hotels in Iran through the lens of the method of life cycle energy analysis (LCEA). The choice of LCEA is deliberate as its scientific rigour in providing accurate carbon footprint appraisals of products and services has long been recognised, but it has been rarely applied to hotels (Filimonau *et al.* 2011a). This study provides further empirical evidence of the practical viability and cost-effectiveness of LCEA when applied within the hotel sector. The choice of Iran as a study geography is also deliberate. Although the country has experienced political isolation, its tourism industry is growing, mostly at the cost of domestic travel (Arefmanesh 2018), and so are the related GHG emissions of Iranian hotels. Carbon mitigation has now become a priority in Iran given the over-dependence of its economy on fossil fuels which has made Iran one of the key global carbon emitters (Ge and Friedrich 2020).

Studied hotels are luxury tourist accommodation properties in Iran whose administration agreed to collaborate on this project by providing researchers with access to their energy use data. In the context of this study, luxury hotels are understood as those tourist accommodation facilities providing significant levels of customer service and consumer amenities to ensure exceptional guest comfort which is line with the definition of luxury hotels used by Sourvinou and Filimonau (2018). Hereafter, wherever the term of luxury hotels is used, it refers to five-star hotels. Studied luxury hotel properties are so-called sector-typical hotels, or archetypes (Lai 2015), defined as the hotels that share operational characteristics of the majority of other hotels of the same comfort category, thus being largely representative of this specific category of hotels in Iran. The focus on the luxury segment of the hotel market is justified by the ability of luxury hotels to transform and lead the hotel sector in its quest towards the goal of environmental sustainability (Gardetti and Torres 2017). By establishing the patterns of energy consumption, revealing the magnitude of the related GHG emissions and adopting approaches to mitigation, luxury hotels in Iran can encourage other hoteliers to join the sector's pursuit towards more environmentally sustainable operations. According to Statistical Center of Iran (2017-2018), there are 36 luxury, five-star, hotels in Iran. This study has targeted 16.6% of them, i.e. 6 hotel properties, aiming to evaluate their energy use and carbon footprint performance. To enable a comparative analysis, the carbon footprint of luxury hotels is compared against the carbon footprint of a budget hotel which, again, is representative of the broader sub-sector of budget hotels in Iran.

The aim of this study is to assess the energy and carbon efficiency of luxury hotels in Iran and propose solutions to enhance their energy and carbon performance. In line with this aim, the research questions that this paper has set to answer are thus as follows: 1) *'What is the carbon footprint of luxury hotels in Iran?'*; 2) *'How does it compare with the carbon footprint of hotels from other comfort categories in Iran?';* 3) *'How does the carbon footprint of luxury hotels in Iran compare against the carbon footprint of luxury hotels in other geographies?'*; and 4) *'What (policy, management, market) interventions are necessary to mitigate the carbon footprint of Iranian hotels?'*.

The rest of the paper is structured as follows. The study background including a review of the literature on the environmental externalities of hotels, a review of the environmental assessment methods, and a background of environmental management in the hotel sector of Iran are provided in Section 2. The details about the research method utilized in this investigation are provided in Section 3. The findings from the analysis and a discussion of these findings are presented in a merged form in section 4. Finally, section 5 elaborates upon the conclusions and policy implications of the findings, as well as provides recommendation for future research.

2. Literature review

2.1. Environmental externalities of hotels

Hotel operations are underpinned by a diversity of functions and services that produce disproportionate environmental externalities (Mensah and Blankson 2013). Hoteliers adopt these functions and services in pursuit of meeting guest expectations (Rico *et al.* 2019) as this is paramount to build customer loyalty which, in turn, raises business profitability (Kasim 2009). Although hotels rely on the provision of numerous environmental services to their guests, they tend to sacrifice the environment for the sake of revenue generation (Oluseyi *et al.* 2016). As a result, a typical hotel can annually consume up to 1000 tonnes of coal (Zhao *et al.* 2012) and release 160-200 kg CO_2 per $1m^2$ of hotel's gross floor area (Legrand *et al.* 2017). Further, per guest night, a typical hotel can use 100-200 gallons of water (Zhang *et al.*, 2010) and generate over 1kg of solid waste (Bohdanowicz and Martinac 2007). At a global scale and in cumulative terms, the environmental externalities of hotels may have exceeded those of such traditionally resource-intense and pollution-heavy industries as chemical, manufacturing and agriculture (Legrand *et al.* 2017). This is alarming given the global hotel sector is rapidly expanding driven by a steady increase in international tourism (UNWTO 2019).

Hoteliers have started realising the disproportionate environmental footprint of hotel operations and their moral obligation to reduce its magnitude (Kasim 2009). As a result, a number of hotels have either adopted or, at least considered the adoption of, mitigation measures (Mensah 2006). However, the drivers behind this adoption remain pragmatic and clearly linked to business profitability (Erdogan and Baris 2007). Indeed, by embracing environmental conservation practices, hoteliers can save over 10% of their annual operational costs (Becken 2013). This can further aid hoteliers in building their business reputation as good corporate citizens, thus enhancing their position in highly competitive tourism marketplaces (Warnken *et al.* 2004). The purely non-pragmatic/non-utilitarian drivers of investing in environmental conservation in hotels are still rare (Abaeian *et al.* 2019).

Scholarly research has attempted to support hoteliers with their mission of (better) environmental sustainability by establishing the magnitude of the environmental impacts of hotels and revealing the main drivers, thus informing mitigation approaches. Table 1 reviews academic studies focusing on the topic of the environmental sustainability in hotels. It shows that recent research has become more specialised, complex and inter-disciplinary. Scholarly interest in the environmental sustainability of hotels has particularly grown since 2011, covering more geographies and addressing a wider range of environmental issues. This notwithstanding, studies focusing on Europe, East Asia & the Pacific outnumber those conducted in South America, Africa and the Middle East.

Table 1. Studies on the environmental sustainability of hotels (since 2000).

Year	Source	Geographical focus	Environmental issue(s) in focus	Scope of analysis			Assessment method
				Assessing magnitude	Establishing drivers	Designing mitigation approaches	
2019	Rico *et al.*	Europe (Spain)	Energy, CO_2 emissions	X	-	X	Screening LCA
2019	Gössling *et al.*	Europe (Spain)	Energy, water, chemicals	-	-	X	Field experiment
2019	Pablo-Romero *et al.*	Europe (Spain)	Energy	X	X	X	Using panel data regression model
2019	Pérez *et al.*	Europe (Spain)	Energy, water, CO_2 emissions	X	-	X	Screening LCA and regression analysis
2019	Dolnicar *et al.*	Europe (Slovenia)	CO_2 emissions	-	-	X	Quasi-experiment
2018	Sheng *et al.*	East Asia (China)	Energy	X	X	X	Computer simulation
2017	Kim and Oldham	North America (USA)	Energy	X	X	-	Regression analysis
2017	Dolnicar *et al.*	Europe (Slovenia)	Energy, water, chemicals	-	-	X	Field experiment
2017	Puig *et al.*	Europe (Spain)	Energy, water, chemicals, waste, GHG emissions	X	-	X	Screening LCA
2017	Cvelbar *et al.*	Europe (Slovenia)	Energy, water, chemicals	-	-	X	Field experiment
2017	Chan *et al.*	East Asia (China)	Indoor air quality	X	-	X	On-site measurements
2017	Michopoulos *et al.*	Europe (Cyprus)	Energy, CO_2 emissions	X	-	X	Carbon footprint analysis
2017	Abdulredha *et al.*	Middle East (Iraq)	Food waste	-	-	X	On-site survey
2017	Gabarda-Mallorquí *et al.*	Europe (Spain)	Water	X	X	-	Generalized linear mixed modelling
2017	Mclennan *et al.*	Asia-Pacific	Water	X	X	-	Regression analysis
2016	Kahn *et al.*	North America	Energy, CO_2 emissions	X	X	-	Carbon footprint analysis
2016	Pirani and Arafat	Middle East (the UAE)	Food waste	X	X	X	Carbon footprint and water footprint analyses
2016	Oluseyi *et al.*	Africa (Nigeria)	Energy, GHG emissions	X	X	-	Carbon footprint and regression analyses
2016	Mardani *et al.*	Middle East (Iran)	Energy	-	-	X	Fuzzy decision-making analysis
2016	Chang *et al.*	North America (USA)	Energy	-	-	X	Scenario-based experiment
2015	Huang *et al.*	East Asia (Taiwan)	Energy, GHG emissions	X	X	-	Screening LCA and regression analysis
2015	Michailidou *et al.*	Europe (Greece)	Energy, water, GHG emissions	X	-	X	ECI and LCA
2015	Hu *et al.*	East Asia (Taiwan)	Energy, water, waste, materials, GHG emissions	X	-	X	Screening LCA (PAS 2050)
2015	Lai	East Asia (Hong Kong)	Energy, water, waste, biomass, GHG emissions	X	X	X	Screening LCA and regression analysis
2014	Tsai *et al.*	East Asia (Taiwan)	Energy, CO_2 emissions	X	X	X	Carbon footprint analysis
2014	Fazelpour *et al.*	Middle East (Iran)	Energy, GHG emissions	-	-	X	Feasibility assessment

2013	Mak *et al*	East Asia (China)	Energy	X	X	X	Regression analysis
2013	Lu *et al*.	East Asia (China)	Energy	X	X	-	Regression analysis
2013	Kallbekken and Sælen	Europe (Norway)	Food waste	-	-	X	Field experiment
2012	Castellani and Sala	Europe (Italy)	Resource use, waste, pollutant emissions	X	-	X	LCA and EFA
2012	Teng *et al*.	East Asia (Taiwan)	Multiple, resource use and non-resource use related, impacts	-	-	X	ECI
2012	Ren *et al*.	Europe (Wales)	Energy, CO_2 emissions	X	-	X	Screening LCA
2012	Lai *et al*.	East Asia (Hong Kong)	Energy, water, waste, GHG emissions	X	-	-	Screening LCA
2012	Aminian	Middle East (Iran)	Energy, water, waste	-	-	X	Qualitative appraisal
2012	Wang	East Asia (Taiwan)	Energy	X	X	-	Regression analysis
2011	Tortella and Tirado	Europe (Spain)	Water	X	X	-	Regression analysis
2011	Chan *et al*.	East Asia (China)	Indoor air quality	X	X	-	Field sampling and laboratory analysis
2011	Chen and Hsieh	East Asia (Taiwan)	Resource use (e.g., land, energy, water, food), waste	X	-	X	EFA
2011	Filimonau *et al*.	Europe (UK)	Energy, CO_2 emissions	X	-	X	Screening LCA
2010	Rossello-Batle *et al*.	Europe (Spain)	Energy, waste, CO_2 emissions	X	-	X	Screening LCA
2010	Xuchao *et al*.	Southeast Asia (Singapore)	Energy, CO_2 emissions	X	X	-	Regression analysis and screening LCA
2009	Priyadarsini *et al*.	Southeast Asia (Singapore)	Energy	X	X	-	Regression analysis
2008	Goldstein *et al*.	North America (the United States)	Energy, water, chemicals	-	-	X	Field experiment
2007	Bohdanowicz and Martinac	Europe	Energy, water	X	X	-	Regression analysis
2006	Chan *et al*.	East Asia (China)	Energy	X	-	X	Field experiment
2005	Önüt and Soner	Middle East (Turkey)	Energy	X	-	X	Data envelopment analysis
2004	Warnken *et al*.	Oceania (Australia)	Energy	X	X	-	Regression analysis
2002	Shiming and Burnett	East Asia (Hong Kong)	Energy	X	X	-	Regression analysis
2002	Deng and Burnett	East Asia (Hong Kong)	Water	X	X	-	Regression analysis
2001	Becken *et al*	Oceania (New Zealand)	Energy	X	X	-	Regression analysis
2000	Deng and Burnett	East Asia (Hong Kong)	Energy	X	X	-	Regression analysis

Within the reviewed literature on the environmental sustainability of hotels, there have been repeated calls for the need to produce more accurate assessments of the GHG emissions (Rosselló-Batle *et al.* 2010; Filimonau *et al.* 2011a; Hu *et al.* 2015). Hotels represent one of the most energy-intense types of commercial buildings thereby making a noticeable contribution to climate change (Dascalaki and Balaras 2004). More research on the carbon footprint of hotels is required to establish the main drivers of energy use, thus designing (more) effective and (better) targeted mitigation strategies (Puig *et al.* 2017). Research on the carbon footprint of hotels is particularly needed for South America, Africa and the Middle East where tourism grows steadily (UNWTO 2019). These regions witness numerous environmental challenges where climate change represents an issue of major concern given its ability to accelerate such related environmental problems as water and food insecurity (Sieghart and Betre 2018). Climate change can further exacerbate numerous political and socio-economic issues that already exist within the regions in question, but also beyond (Stang 2016). One of the reasons behind the (yet) limited research agenda on the assessment of the GHG emissions from hotels in South America, Africa and the Middle East is in the under-developed methodological base of carbon footprint appraisals (Filimonau *et al.* 2011b).

2.2. Methods to assess the environmental / carbon footprint of hotels

2.2.1. Ecological Footprint Analysis (EFA)

The method of Ecological Footprint Analysis (EFA) represents an established tool to appraise the environmental externalities of products, services, economic sectors and entire countries (Wackernagel and Ress 1996). It is therefore unsurprising that past research has attempted to adopt it for application in tourism (see, for instance, World Wildlife Fund-UK 2002; Gössling *et al.* 2002; Patterson *et al.* 2007). The results of this research have however underlined such shortcomings of EFA as its high data quality requirements, tendency to over-estimate actual environmental impacts and limited value to inform the design of mitigation strategies (Hunter and Shaw 2007). Hence, only two studies on the environmental externalities of hotels are explicitly grounded on the method of EFA (Table 1) which is mainly because poor availability and insufficient quality of data on the environmental footprint of hotels makes it difficult to produce reliable and accurate assessments (Chen and Hsieh 2011). This was explicitly identified by Castellani and Sala (2012) who applied EFA to various types of hotels in Italy but concluded that the lack of site-specific data hampered the accuracy of appraisal and hindered the production of conclusions that could be of value for hotel administrations. By applying EFA to hotels in Taiwan, Chen and Hsieh (2011) generated more meaningful results due to better quality of primary data provided by hotel managers. The study established that energy use and food consumption were responsible for over 90% of the environmental footprint of the studied hotels. Grounding on this, various derivatives of EFA have been adopted to assess the water and carbon footprint of hotels (Table 1). These varied from narrow, specialised studies aiming to establish the impacts of hot water production technologies in hotels (Michopoulos *et al.* 2017), to the industry-broad research projects striving to evaluate energy efficiency of hotels across the entire country (Kahn *et al.* 2016).

2.2.2. Environmental Composite Indicator/Index (ECI)

The Organization for Economic Co-operation and Development (OECD) and the Joint Research Center (JCR) of the European Commission have proposed the method of Environmental Composite Indicator (ECI) to appraise the environmental externalities of products and services (JRC-European Commission 2008). The method is unique in that it can provide a balanced/weighted evaluation of the environmental impacts of a product or service across a number of impact categories (Dočekalová and Kocmanová 2015) and produce a clear set of managerial recommendations for impact mitigation (Mendola and Volo 2017). The application of ECI to hotels has however been limited to the study on the energy performance and carbon reduction potential of hotels in Taiwan (Teng *et al.* 2012) and to the appraisal of the environmental impacts of hotels in Greece (Michailidou *et al.* 2015), Table 1.

Both studies highlighted such important shortcomings of ECI as poor data availability and quality (Blancas *et al* 2016) alongside the element of subjectivity involved in the evaluation, with subsequent weighting, of the environmental impacts of hotels (Salvati 2014).

2.2.3. Life Cycle Assessment (LCA)

The method of Life Cycle Assessment (LCA) has long been recognised as the most comprehensive approach to appraising the environmental externalities of products and services given it is underpinned by the 'cradle-to-grave' considerations (Klöpffer 2003). Similar to ECI, LCA can assess multiple environmental impacts including those attributed to the non-operational inputs of energy and material (Frischknecht *et al.* 2007). Unlike EFA which provides a limited insight into possible impact mitigation options for managers, LCA can inform the design of mitigation strategies by outlining areas (with a product's or service's lifecycle) with the largest environmental footprint (Wolf *et al.* 2012).

As for the potential of LCA to be applied for assessment of the environmental externalities of hotels, similar to the methods of EFA and ECI, its major shortcoming is in data availability (Schianetz *et al.* 2007). The truly comprehensive, from cradle-to-grave, assessment requires primary data of exceptional quality, which is rarely the case for hotels (Castellani and Sala 2012). Another drawback is the cost of analysis as, for better efficiency, the lifecycle data need to be processed in specialist software which is expensive for hotels to procure and difficult to operate (De Camillis *et al.* 2010). To make the method of LCA more cost-effective, a number of streamlined, or screening, derivatives have emerged. For example, the method of Life Cycle Energy Analysis (LCEA) has been proposed to appraise the energy consumption and assess the related carbon footprint of hotels (Filimonau 2016). By focusing on a single environment impact, i.e. climate change, LCEA is able to (better) address the issue of data quality whilst concurrently reducing the cost of assessments given that no laborious field work and analysis is required (Filimonau *et al.* 2011a). A number of studies have applied such screening LCA methods in practice (Table 1) and Table 2 reviews the instances of their application to hotels in detail.

Table 2. LCA-based studies of hotels.

Reference	Object and location	Functional unit/ Benchmarking indicator	System boundary and scope					Main source of environmental impacts in hotels / Identified hotspots	Primary data sources
			Building construction	Operation	Refurbishment	Demolition	Transportation		
Rico et al. (2019)	53 hotels in Spain	Per guest night stay; per room day	-	X	-	-	-	Electricity consumption	Secondary data from the literature
Neugebauer *et al.* (2020)	Hotel in Germany	Per guest night stay	-	X	-	-	-	Not clearly stated	Secondary data from the literature
Pérez *et al.* (2019)	12 hotels in Spain	Per guest night stay	-	X	-	-	-	Electricity consumption	On-site data collection
Puig *et al.* (2017)	14 hotels in Spain	Per guest night stay	-	X[a]	-	-	-	Electricity and fuel consumption in the use phase	On-site data collection
Hu *et al.* (2015)	Hotel in Taiwan	Per gross floor area and guest night stay	-	X[b]	-	-	X[c]	Electricity consumption in the use phase	On-site data collection
Michailidou *et al.* (2015)	16 hotels in Greece	Surface area; Guest nights; Number of guest rooms	-	X	-	-	X[d]	Not clearly stated	On-site data collection
Lai (2015)	3 hotels in Hong Kong	Total floor area and number of guest rooms	-	X	-	-	X[e]	Electricity consumption in the use phase	On-site data collection
Huang *et al.* (2015)	58 hotels in Taiwan	Per gross floor area	-	X	-	-	-	Electricity consumption	Phone interviews and on-site data collection
El Hanandeh (2013)	Hotels in Saudi Arabia	Per guest night stay	X	X	-	-	-	Not clearly stated	Secondary data from the literature
Filimonau *et al.* (2013)	Hotel in Portugal	Per guest night stay	X[f]	X	-	-	-	Direct emissions	On-site data collection
Castellani and Sala (2012)	Hotel in Italy	Per guest night stay	X	X[g]	X	X	-	Electricity use in the operational phase	On-site data collection
Lai *et al.* (2012)	Hotel in Hong Kong	Per room-day	-	X	-	-	-	Electricity usage	On-site data collection
Ren *et al.* (2012)	Hotel in the UK	Not defined	X	-	-	-	X[h]	Materials delivery	On-site data
Filimonau *et al.* (2011b)	Hotel in the UK	Per guest night stay	-	X	-	-	-	Electricity consumption	Secondary data from the literature
Filimonau *et al.* (2011a)	2 hotels in the UK	Per gross floor area and number of guest nights	X[f]	X[i]	-	-	X[j]	Electricity use in the operational phase	On-site data collection
Xuchao *et al.* (2010)	29 hotels in Singapore	Per gross floor area and number of room nights	-	X	-	-	-	Electricity consumption	Data from a national survey
Rosselló-Batle *et al.* (2010)	2 hotels in Spain	Per $1m^2$ of built area	X[k]	X[l]	X	X[m]	X[n]	Operational phase	On-site data collection

Remarks:

a. in addition to energy and water consumption, included use of chemicals, waste generation and treatment

b. included resource consumption, outsourced laundry services and sewage disposal discharge
c. included outsourced laundry services, transport of goods to the hotel and removal of waste
d. included travel by hotel guests
e. included travel by hotel staff and guests
f. based on estimates extracted from the literature
g. included resource consumption, waste generation and food services
h. included all construction-related transportation activities
i. included operational energy use and energy embodied in catering and laundry services
j. included transportation service for food delivery
k. included construction materials and construction waste
l. included operational energy use and waste generation
m. an approximation was done
n. restricted to transportation in the demolition phase

Table 2 demonstrates that most LCA-based studies are concerned with carbon footprint, justifying this by its disproportionate contribution to the overall environmental externalities of hotels (Xuchao *et al* 2010). The issue of carbon footprint is further seen as being of prime concern for hotel administration given that energy conservation is closely linked to business profitability and reputation (Rosselló-Batle *et al* 2010). Lastly, undertaking a multi-impact appraisal is often considered unviable due to the poor quality of non-energy use data and the high cost of their procurement (Castellani and Sala 2012); it is further because many hotel managers do not clearly understand such environmental externalities as, for example, eco-toxicity or eutrophication and how these can be mitigated in situ (Filimonau *et al.* 2011a).

Due to problems with data availability and accessibility, most studies choose to focus on specific stages of the hotel's business lifecycle. For instance, Ren *et al* (2012) appraised the carbon implications of constructing a hotel building in the UK and Huang *et al.* (2015) assessed the GHG emissions from hotel operations in Taiwan. Past research has concluded that the operational stage of a hotel business's lifecycle generates the largest proportion of its total carbon footprint and should therefore be focussed on for better cost-effectiveness of appraisals (Filimonau 2016). For example, Rosselló-Batle *et al.* (2010) revealed that the operational phase of hotel buildings' lifecycle in a sample of hotels in Spain was 6-11 times more carbon intense than the construction phase. Likewise, Hu *et al.* (2015) found that the operational phase of a hotel business in Taiwan was responsible for 88% of its total carbon footprint.Likewise, Puig *et al.* (2017) identified that operational energy use in Spanish hotels produced 75% of their total GHG emissions while the contribution of water consumption, use of chemicals and solid waste generation was marginal. This contribution was calculated even higher at 97% in the recent study conducted by Rico et al. (2019). Following these findings, Filimonau *et al.* (2011a) proposed that future carbon footprint appraisals of hotels should be concerned with collecting primary data on operational energy use only while the non-operational GHG emissions should be estimated as being equal to 15% of the operational carbon footprint. This is to make studies more cost-, time- and labour-effective, but also to tackle the issue of primary data availability and quality.

In summary, screening LCA represents an accurate, yet cost-effective, method of appraising GHG emissions of hotels, establishing the 'hot-spots' in carbon footprint generation and highlighting mitigation opportunities for hotel administration. This notwithstanding, studies underpinned by this method remain small in number and cover only a handful of geographies. No research has attempted to adopt LCA to appraise the GHG emissions of hotels in Iran, a large Middle East's economy with an established hotel sector. This study will partially fill this knowledge gap.

2.3. The hotel sector of Iran and the environmental management within

Despite the abundance of natural and cultural heritage which traditionally attracts tourists, the tourism market in Iran is immature (Morakabati 2011). Two fundamental, internal and external, factors hinder tourism development. The internal factor is attributed to the organisational and institutional challenges in Iran. Up until August 2019, there was no dedicated Iranian ministry to deal with tourism and any tourism planning and development tasks were fulfilled by a public body called the *'Iran Cultural Heritage, Handicrafts and Tourism Organization'*. The work of this organisation was repeatedly criticized for the lack of tourism-specific expertise, poor leadership and limited agility to market changes (Khodadadi 2016a). The external factor in the under-development of the tourism market in Iran relates to the political and economic challenges experienced by the country on the international arena. This includes punitive sanctions, currency fluctuations, economic over-dependence on oil revenues and the prevalence of Iran-phobia among prospective international tourists (Khodadadi 2016a).

Due to these factors, in recent years, the inbound tourism market in Iran has stagnated. From 2013 to 2017, the number of international tourists had fluctuated at around 5 million. Followed by an increase of 4.2% over the period of 2013/14, tourist numbers peaked at just over 5.2 million in 2015 (UNWTO 2017), then fell back to just under 4.9 million in 2016 (UNWTO 2018). After years of stagnation, in 2018, inbound tourism reached its second highest point at circa 7.3 million (UNWTO 2019). Most international tourists arrive to Iran from the neighbouring countries of Iraq (approximately 2.6 million), Azerbaijan (circa 1.8 million), Afghanistan (circa 1 million), Turkey (just under 0.9 million) and Pakistan (nearly 0.3 million) (ICHHTO 2019-2020). Despite a relatively small size of inbound tourism in Iran, the contribution of this industry to the country's GDP is estimated at 7.5% (Central Bank of Iran 2018) which signifies its power as an economic activity of national importance, especially in light of Iran's over-dependence on oil extraction. Domestic tourism contributes with nearly 8o% to tourism's GDP of Iran (WTTC 2017) with 182 million trips undertaken by Iranians every year (ICHHTO 2018-2019).

The hotel sector in Iran reflects the effect of the current stagnation in national tourism. Due to a small number of international tourists, foreign hospitality brands are reluctant to invest in Iran (Ghaderi *et al.* 2019). Hence, local hospitality companies, driven by a steady growth in domestic tourism, have been leading the development of the national hotel market (Khodadadi 2016b). Today, there are 1387 registered hotels in Iran (accommodating 305510 beds) with the low-cost/low-comfort market categories, i.e. one- and two-star hotels, cumulatively occupying 52% of the Iranian hotel market (370 and 348 properties, respectively) followed by budget, three-star, hotels (21% or 294 properties), unclassified/non-star (17% or 234 properties) and upmarket, four-star, hotels (7% or 105 properties) (ICHHTO 2018-2019). 3% of the market share (or 36 properties) belongs to luxury, five-star, hotels (SCI 2017-2018).

The dominance of low-cost/low-comfort and budget hotel categories is due to the low purchasing power of domestic tourists in Iran. These properties are usually very basic with limited guest amenities (SCI 2020). The upmarket and, especially, luxury hotels cater for international tourists as well domestic business travellers and domestic affluent tourists. These properties normally have a broad range of guest amenities on offer. Further, compared to other hotel categories, luxury hotels have better (financial and labour) resources which, in theory, should enable them to invest in solving such operational issues as the environmental sustainability. In line with its Sixth Five-Year Economic, Cultural, and Social Development Plan (2016–2021), the Iranian government is keen to increase the total number of hotels, especially four- and five-star properties, in an attempt to build loyalty of international and business tourists (ICHHTO 2018-2019).

Scholarly research on the environmental management in Iranian hotels lags behind and the Scopus/Google Scholar search undertaken on this topic revealed only three studies published in peer-reviewed, English-speaking, academic literature (Aminian 2012; Fazaelpour *et al.* 2014; Mardani *et al.* 2016), (Table 1). The focus of these studies was however on either energy efficiency management or environmental decision-making in hotels, rather than on energy and carbon audit. It is argued that effective environmental decision-making in hotels should be underpinned by a sound understanding of the exact magnitude of environmental issues in focus, which is the exact focus of this study.

Despite the lack of research, it is perceived that hotels in Iran tend to underestimate the value played by various environmental services in their day-to-day operations and, as a result, overlook environmental standards in hotel building construction and design, consume excessive energy, water and other resources and mismanage waste. It is further perceived that hotels in Iran take a passive role in training their staff and educating guests in energy conservation. Importantly, the hotel sector in Iran has not been captured by the national inventories of GHG emissions (see, for example, National Climate Change Office 2010). In fact, such inventories treat hotels as part of the commercial building stock which hampers distinguishing their carbon performance from that of other commercial buildings in Iran. This further impedes a comparative analysis of the GHG emissions of Iranian hotels against hotels of similar comfort categories located in other geographies. The above underlines an important knowledge gap and justifies the need for the current study.

3. Methods

3.1. Case study hotels

Study participants were recruited from among luxury hotels in Iran. To this end, faxes were sent to owners/managers of all luxury hotel properties introducing the project and explaining its goals. This was followed up with personal phone calls aiming at providing further project's details and securing permission of hotel managers to partake in an energy audit.

Six hotels, making up 17% of all luxury hotels in Iran (SCI, 2017-2018), provided consent to participate in this study. Not being limited to a narrow geographical area, these surveyed hotels came from different regions of Iran, despite the added difficulties to field visits. It does matter since weather conditions, flow of capital and knowledge, characteristics of tourism markets and, following these, hotels' operational and physical features, differ from region to region in Iran or, indeed, in other tourist destinations. Three of the surveyed hotels belonged to a large owner and operator of luxury, five-star, hotels in Iran. These three properties were located in Mashhad, Kerman and Khuzestan provinces of Iran. The remaining three properties each owned by a separate hotel chain are located in Tehran (Figure 1). While Tehran is an ideal destination for business travellers, Mashhad is one of the main hubs of religious tourism in Iran. In addition to their historical attractiveness, Kerman, due to proximity to the Lut dessert, and Ahvaz, due to proximity to important rivers and the Persian Gulf coast, are popular with leisure holidaymakers. Moreover, because of the differences in their surrounding natural environment and population density, these cities are representative of different climates in Iran (Roshan *et al.* 2017).

The physical and operational parameters of the surveyed luxury hotels of relevance to this study differ from each other (Table 3). For the purpose of data privacy, they are labelled thereafter as Hotel A-F. As can be seen in the table, there is a significant discrepancy between GFA and number of guest nights of Hotel F and those of Hotel C, for instance. Another noticeable difference is observed between occupancy rates of Hotels F and E, where the occupancy rate of Hotel F is 1.6 times larger than the one recorded for hotel E. However, the case study hotels are representative of the luxury hotel category in Iran. That is, there are minor differences between their major physical and operational characteristics and those of Iranian luxury hotels not investigated in this study. This was revealed through personal communication with the representatives of these companies' administrations and the chief of the Iran's Hotel Associations, where it was realized that their room occupancy (40-60%) and annual number of guest nights (above 20000) were similar to other luxury hotel properties in Iran. This was further re-confirmed by comparing the features of the case studied properties with those reported on corporate websites of other luxury hotels in Iran. All this evidence suggests that the case study hotels can be labelled as sector-typical, or representative, archetypes for the luxury hotel sector of Iran. This is particularly valuable as this means that the results of the carbon footprint appraisal undertaken in this study can be subsequently extrapolated to provide an insight into the GHG emissions of other luxury hotel properties in Iran.

For a comparative analysis, a case study hotel representing a low-cost/low-comfort segment of the hotel market in Iran was added to the sample (labelled thereafter as Hotel X). This was an independent city hotel and its choice was driven by its operational characteristics that were largely typical, representative, of other hotels in Iran within the low-cost/low-comfort category in terms of their room occupancy rates (40-50%) and the annual number of guest night stays (5000-10000), Table 3.

Table 3. General characteristics of the case study hotels. Data are valid for the operations year of 2016-2017.

Characteristic	Hotel A	Hotel B	Hotel C	Hotel D	Hotel E	Hotel F	Hotel X
Location	Mashhad, Razavi Khorasan province	Kerman, Kerman province	Ahvaz, Khuzestan province	Tehran, Tehran province	Tehran, Tehran province	Tehran, Tehran province	Abadeh, Fars province
Geography type	City hotel						
Operational season	Full, 365 days						
Category	5*	5*	5*	5*	5*	5*	2*
Number of floors	6+5+6 floors	11 floors	7 floors	14 floors	20 floors	29 floors	4 floors
Type of a hotel building construction	Three interconnected buildings	Building of separate standing					
GFA (m^2)	39135.14	32000	10247.5	23400	23000	51800	2440
Year of building construction	1995	1994	1968	1969	1969	1971	1971
Number of guestrooms	229	197	135	374	177	489	28
Annual occupancy (in % of rooms occupied)	50%	42%	60%	53%	38%	63%	40%
Occupancy (in % of beds occupied)	15%	17%	22%	-	27%	37%	25%
Number of guest nights per annum	25322	24842	23673	-	36886	90664	8172
In-house laundry	Yes	Yes	Yes	Yes	Yes	Yes	Yes
In-house restaurant	Yes	Yes	Yes	Yes	Yes	Yes	Yes

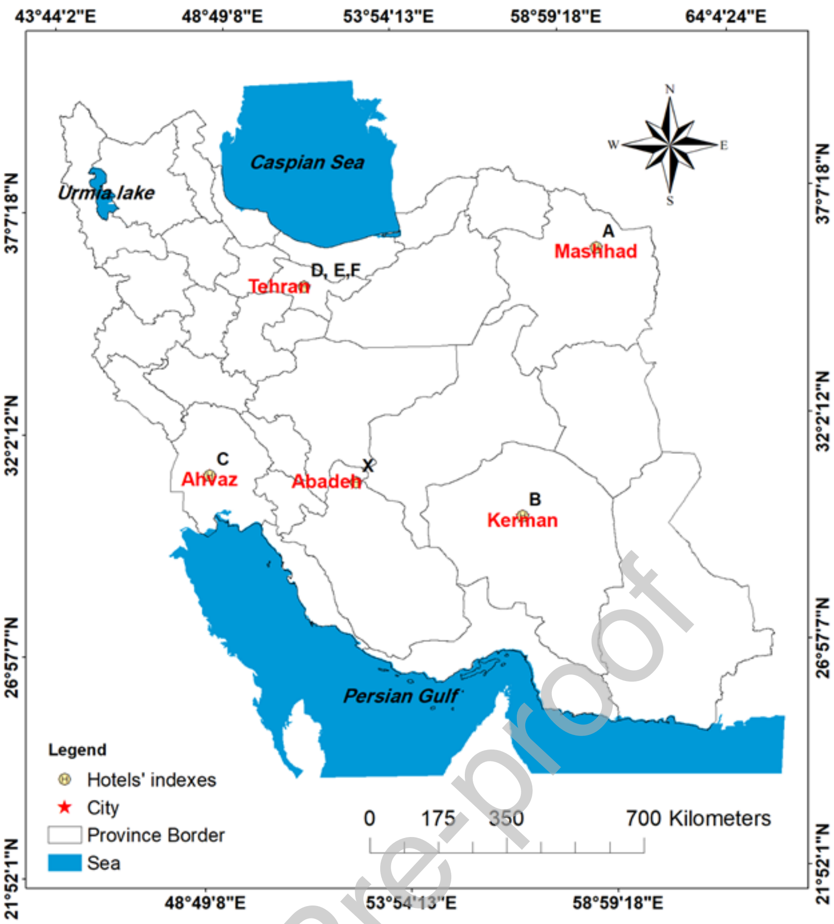
Facilities and services offered	Guest accommodation / Catering / Laundry / Conference facilities / Sports facilities / Guest shop/ Parking	Guest accommodation / Catering / Laundry / Parking
Energy-consuming services	Guest rooms, HVAC, hot water, cooking, laundry, elevators	
Main energy sources	Electricity (lighting, heating, cooling, ventilation, plug-in equipment, refrigerators, elevators); Natural gas (cooking, hot water, heating)	

3.2. Primary data collection

Primary data were collected via an annual on-site survey of energy use conducted upon securing consent of case study hotels' administration. The survey ran during the course of the Iranian calendar year, i.e. beginning from 21st March 2016 to 20th March 2017, and aimed to accurately record all instances of energy use in the studied hotels' buildings. Survey data were subsequently compared with energy invoices provided by the studied hotels in order to confirm survey data reliability and validate the correctness of seasonal patterns of energy use.

Following this, interviews with senior managers of the studied hotels were held. This procedure follows the approach of carbon footprint assessment introduced by Koiwanit and Filimonau (2021). During these interviews, the data collected in the survey and subsequently validated via desk-based research, as per above, were presented to senior hotel managers. Managers were requested to confirm that the primary data obtained were consistent with their expectations of the energy performance of their hotels and in line with such data for past years. This was to ensure that the data collected contained no outliers caused, for example, by unusual seasonal or annual variations in room/guest occupancy This was further to guarantee that the data were representative of a 'normal' hotel building's pattern of energy use across past years of business operations. Interviews confirmed this was the case.

Figure 1. Geographical locations of the case studied hotels



3.3. Primary data analysis

To convert energy data into the corresponding greenhouse gas emissions, appropriate emission factors must be adopted (Filimonau 2016). The standard emission factors annually released by the Iranian Ministry of Energy (2018-2019) were employed for this purpose. Hotels in Iran consume energy from two sources: electricity (predominantly for air-conditioning and lightning) and natural gas (mostly for heating and cooking). Given the mixture of electricity production in the country, in 2016-2017, 1 kWh of electricity in Iran generated an average of 0.64 CO_2 kg. For natural gas, the default emission factor is 4.89 kg/m^3 which is an equivalent of 0.47 CO_2 kg/kWh. For the purpose of unifying the two units, the electricity equivalent of natural gas, i.e. 10.34 kWh/m^3 (Iranian Ministry of Energy 2018-2019), was utilized.

Energy use and the related carbon footprint were calculated *per guest night* stay and per *unit of gross floor area* (m^2 of GFA or energy use index in the case of energy consumption) of the studied hotels (Table 4). The latter is a well-established unit in research on energy use in commercial buildings, including hotels (see, for example, Dascalaki and Balaras 2004; Oluseyi *et al.* 2016; Puig *et al.* 2017) while the former indicator has been repeatedly used in studies on energy consumption and carbon footprint in the hotel sector (see, for instance Castellani and Sala 2012; De Camillis *et al.* 2010; Filimonau *et al.* 2011a; Rico et al. 2019). Both indicators were employed to enable analysis of this study's findings against the results reported in past research.

Table 4. Energy use characteristics of the surveyed hotels.

Characteristic	**Hotel A**	**Hotel B**	**Hotel C**	**Hotel D**	**Hotel E**	**Hotel F**	**Hotel X**
Energy use (kWh/guest night):							
TOTAL	867 (100%)	448 (100%)	189 (100%)	-	344(100%)	229(100%)	76 (100%)
Electricity	116 (13%)	81 (18%)	106 (56%)	-	120 (35%)	64(28%)	10 (13%)
Natural gas	751 (87%)	367 (82%)	83 (44%)	-	224 (65%)	165(72%)	66 (87%)
AVERAGED	*415*						*76*
Energy use index (EUI, kWh/m²/year):							
TOTAL	561 (100%)	348 (100%)	438 (100%)	650(100%)	552(100%)	401(100%)	255 (100%)
Electricity	75 (13%)	63 (18%)	246 (56%)	117 (18%)	192 (35%)	112 (28%)	35 (13%)
Natural gas	486 (87%)	285 (82%)	192 (44%)	533 (82%)	360 (65%)	289 (72%)	220 (87%)
AVERAGED	*492*						*255*

Following the guidelines of screening LCA (Puig *et al.* 2017), a system boundary was set up for analysis. This included all instances of energy use in hotel operations for such purposes as: guest stay (including laundry), catering, leisure, business. Similar to other studies (Filimonau *et al.* 2011a), instances of indirect/non-operational energy use (energy embodied in food procurement, hotel's building, furniture and equipment) were excluded from analysis due to data availability.

4. Results and discussion

4.1. Operational energy use

Figure 2 shows that operational energy consumption in the case study hotels varies significantly across the sample, with Hotels A and F standing out as heavy energy users. For Hotel F, excessive energy use was due to the size of the hotel's property which is the largest in the studied sample (489 guest rooms and GFA of 51800 m^2), Table 3. Interviews with the Hotel A's administration revealed that this hotel's excessive energy use was largely attributed to the property's location in the north-east of Iran which is characterised by colder climate (Roshan *et al.* 2017). This is reflected in excessive use of natural gas (87% of the total energy consumption) by Hotel A for heating, especially in winter. The physical parameters of the Hotel A also played a role in its excessive energy consumption. In addition to being the second largest hotel within the studied sample in terms of GFA (Table 3), its building is designed in the Y-shape and has a number of outbuildings with multiple exits. This brings about higher energy inefficiency in comparison with a more 'traditional' design of hotel buildings (Sozer 2010). For instance, all other hotels under study are represented by a single building.

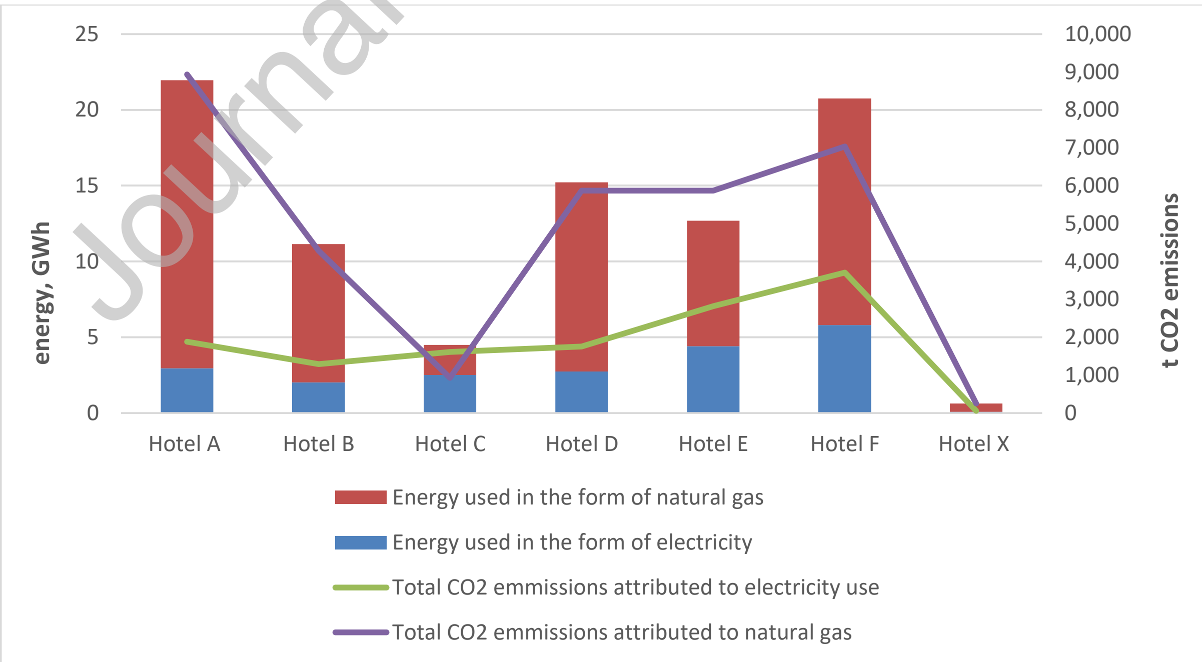


Figure 2. Energy use and carbon emissions of the studied hotels

Interestingly, despite its larger size (Table 3), Hotel F slightly outperforms Hotel A in terms of energy usage (Figure 2). In addition to the factors of hotel's location and building design discussed above, this is also a result of implementing some energy conservation measures. According to its administration, Hotel F is one of the first hotels in Iran to begin investing in such technologies as the Building Management Systems (BMS) and Computerised Maintenance Management System (CMMS). These technologies enable Hotel F to more effectively manage energy use compared to Hotel A which has no such technology in place. Hotel F is located in Tehran which is a mainstay of tourist demand in Iran. The factor of location played an important role in the decision of this hotel's administration to avail of energy saving technologies. Better availability of finance and relevant technologies (Dascalaki and Balaras 2004) alongside growing expectations of international hotel guests of the environmental sustainability measures adopted by hotels (Kasim 2009) represent significant drivers of the industry's investment in energy conservation, which holds true for Iran (Mardani *et al.* 2016).

Smaller size (Table 3) explained the relatively small energy consumption pattern of Hotel C. If the size of this hotel tripled, thus reaching the figure of other studied luxury hotels within the sample, then its energy use would be comparable to that of Hotel B (Figure 2). Interestingly, however, due to higher occupancy, energy consumption of Hotel C per guest night is higher than that of Hotel B (Table 4). These findings confirm that size of a hotel's property (Deng and Burnett 2000) and its occupancy rate (Xuchao *et al.* 2010) represent the major determinants of energy consumption patterns in the hotel sector. Another distinctive feature of Hotel C is in its over-reliance on electricity (Figure 2). This is attributed to the factor of hotel's location in the south-west of Iran characterised by dry and warm climate (Roshan *et al.* 2017). In line with this, Hotel C consumes disproportionate energy for air-conditioning/cooling/ventilating, especially in spring and summer seasons.

When energy performance of luxury hotels was compared against that of a low-cost Hotel X, substantial differences were detected. The overall energy use of Hotel X was significantly lower (Figure 2) as it consumed 11 times less energy than Hotel A and almost 5 times less energy than Hotel C. Likewise, calculations *per guest night* stay indicated that Hotel X consumed 7 times and 2.5 times less energy than Hotel A and C, respectively (Table 4). The main reason behind this is linked to the difference in the availability of guest amenities and services in the studied hotels. For example, whereas the cooling systems in Hotels A-F are central, Hotel X utilizes smaller-scale evaporative coolers. These are installed directly in guest rooms but, unlike central systems where hotel guests can easily adjust the settings of heat/cold via in-room thermostats, these offer limited/no scope for guests' manipulation and/or intervention (Yu and Chan 2006). This technology is more suitable for low-cost hotels not only because it is cheaper to install, but also due to lower expectations of clientele of such hotels of the levels of in-room comfort. Further, although Hotel X provides catering and in-house laundry services to its guests, according to this hotel's administration, these are of smaller-scale and of more limited range compared to Hotels A-F. These findings provide further evidence to the literature which has long established hotel's class/comfort category as a determinant of its energy use patterns (Becken *et al.* 2001; Lai 2015; Trung and Kumar 2005).

Table 5 compares averaged energy performance of the studied hotels with the figures reported in past research. It shows that luxury hotels in Iran are generally significantly more energy-intense regardless of the unit of analysis. With an averaged value of about 415 kWh *per guest night* (Table 4), luxury hotels in Iran have no comparable hotels across the world. The closest value of 90 kWh/guest night recorded for some European hotels (Bohdanowicz and Martinac 2007) is more than 4 times lower than the one identified for Iran. In addition, the former number is over a decade old while the Iranian figure is modern. Such significant discrepancy is partially attributed to exceptionally low guest occupancy rates in Iranian hotels, i.e. 15-37% (Table 3), compared against the rate of 84% typical for London (PwC 2019), for example. This, in turn, is due to the punitive economic sanctions preventing the more rapid development of international tourism in Iran. Another reason might be in the lack of hotel administration's interest in saving energy due to its affordability in Iran.

Further, Table 5 demonstrates that, with an averaged value of about 492 kWh per unit of GFA, the pattern of energy consumption is only similar to the one typical of hotels in Singapore (Xuchao *et al.* 2010; Priyadarsini *et al.* 2009) and in Greece (Pieri *et al.* 2015) – all within the range of 400-500 kWh per unit of GFA. Concurrently, energy use in Iranian luxury hotels is 2.7 times higher than those of their counterparts in China (Sheng *et al.* 2018) where the lowest pattern of energy consumption has been recorded to date (Table 5). This performance gap can be due to the fact that, unlike in the case of most hotels overseas (Xuchao *et al.* 2010; Huang *et al.* 2015; Yao *et al.* 2015), energy consumption of luxury hotels in Iran is more reliant on natural gas, the combustion of which generates higher energy value than that in Chinese hotels (Sheng *et al.* 2018), for example. Besides, as stressed by the hotel's administration interviewed, in the result of inadequate manufacturing standards followed by domestic producers in Iran alongside the procurement limitations imposed by punitive international sanctions, energy efficiency of the electric and electronic equipment operated by the case study hotels, especially in the functional areas of kitchen, laundry and powerhouse, is significantly lower compared to that utilized in other geographical markets. The inability to procure modern electric and electronic equipment suggests that energy efficiency of Iranian hotels cannot be improved via retrofitting which holds significant potential to reduce energy intensity of the hotels sector (Xu *et al.* 2011).

Table 5. Operational energy use and carbon footprint of hotels worldwide. *Italics* indicate those figures that are similar to the ones identified in this study.

Source	Location	Sample size	Hotel category LU: luxury, 5 star/ top class/ international/ business hotels UP: up-market/ 4 star / standard tourist/ resort hotels MID: mid-market/ 3 star/ general hotels LC: low comfort/ 2 star hotels ONE: 1 star hotels UC: unclassified	Average EUI (kWh/m^2/ year)	Average kWh/ guest night/ year	Average kg CO_2e/ m^2/ year	Average kg CO_2e/ guest night/ year	Reference year of data
This study	*Iran*	*6*	*LU*	*492*	*415*	*254*	*212*	*2016-17*
Rico et al. (2019)	Spain	6	LU	-	62	-	22	2016
		31	UP	-	39	-	13	
		13	MID	-	21	-	7	
		7	LC	-	12	-	4	
		7	ONE	-	11	-	4	
Pérez *et al.* (2019)	Spain	2	LU	-	70	-	38	2007-2015
		7	UP	-	21	-	12	
		3	MID	-	12	-	6	
Sheng et *al.* (2018)	China	310	LU	80-280	-	-	-	2018
Teng *et al.* (2017)	China	3	MID	92	-	-	-	2017
Bianco *et al.* (2017)	Italy	393	LU	230	-	-	-	2014
		5354	UP					
		15243	MID					
Puig *et al.* (2017)	Spain	3	LU	-	56	-	22	2010-2013
		6	UP		31		12	
		3	MID		13		3	
		2	LC		64		23	
Oluseyi *et al.* (2016)	Nigeria	7	LU	307	-	-	-	2014
		7	UP	258				
		7	MID	318				
		7	LC	142				
Pieri *et al.* (2015)	Greece	9	LU	*420*	-	-	10-50	2010-2011
		12	UP					
		8	MID					
		1	LC					
Yao *et al.* (2015)	China	15	LU	215	-	-	-	2015
		15	UP	235				
		15	MID	215.7				
Huang *et al.* (2015)	Taiwan	39	LU	281	-	132	29	2012
		19	UP	249				
Hu *et al.* (2015)	Taiwan	1	LU	-	-	176	157	2011-2012
Tsai *et al.* (2014)	Taiwan	12	LU	-	-	-	29	2011-2012
		7	UP				19	
		22	MID				13	
		24	LC				6	
Lu *et al.* (2013)	China	20	LU	132	32	-	-	2010
		7	UP					
Lai *et al.* (2012)	Hong Kong	1	UP	-	-	173	-	2012
Wang (2012)	Taiwan	45	LU	280	62	-	-	2010
		19	UP	238	55			
		116	MID	186	55			
		20	LC	144	24			
Filimonau *et al.* (2011a)	The UK	2	MID	213	13	95	6	2008
Xuchao *et al.* (2010)	Singapore	11	LU	*427*	-	*222*	-	2004
		13	UP					
		5	MID					
Rosselló-Batle *et al.* (2010)	Spain	2	UP	140	-	96	-	2007

Priyadarsini *et al*. (2009)	Singapore	11	LU	*458*	-	-	-	2005-2006
		13	UP	*445*				
		5	MID	283				
Bohdanowicz and Martinac (2007)	Europe	73	UP	364	90	-	-	2004
		111	MID	285	48			
Trung and Kumar (2005)	Vietnam	9	UP	141	-	-	-	2000
		25	MID	143				
		12	LC	101				
Önüt and Soner (2005)	Greece	32	LU	389	-	-	-	2005
Dascalaki and Balaras (2004)	Italy	1	MID	215	-	-	-	2004
	Greece	1	MID	174				
	France	1	MID	280				
	Spain	1	MID	287				
Becken *et al.* (2001)	New Zealand	30	UC	159	43	-	-	1999
Deng and Burnett (2000)	Hong Kong	16	UC	564	-	-	-	1995
Santamouris *et al.* (1996)	Greece	158	UC	273	-	-	-	1996

Another substantial gap in energy use can be observed when the discrepancy between the energy performance of Iranian luxury hotels is compared against that of their counterparts in Spain (Puig *et al.* 2017; Rico et al. 2019) and Taiwan (Wang 2012), Table 5. It is argued that this is partially because of the lack of government- and/or industry-driven interventions to monitor and, subsequently, regulate energy usage within the hotel sector of Iran. It is deemed that this is also a result of insufficient awareness among Iranian hoteliers of energy reduction measures and, more importantly, the benefits these measures can provide their businesses with. Indeed, unlike in other countries (Filimonau 2016), the low costs of fossil fuels in Iran may prevent hotel administration from adopting the vision of cost-saving as a prime motivator of investing in energy efficiency. Low environmental awareness of domestic tourists does not prompt hoteliers to reduce energy consumption, suggesting energy conservation can only be driven by the good will of the hotel's administration. Accordingly, the energy conservation measures undertaken by luxury hotels in Iran are not substantially different from those adopted in low-cost hotels, and remain inadequate when compared to international standards (Michailidou *et al.* 2015).

4.2. Operational CO_2 emissions

Figure 2 shows that the CO_2 emissions of the studied luxury hotels in Iran are attributed to natural gas consumption with an exception of Hotel C whose over-reliance on electricity due to its geographical location was explained earlier. The highest share of natural gas in the carbon footprint was recorded for Hotel A (83%) which is because of the particular building design, size of the property, geographical location, higher number of guest rooms and higher guest occupancy rates. Table 6 compares the carbon performance of the studied hotels. It indicates correlation between higher levels of guest functions and services with the generation of higher amounts of CO_2 emissions when calculated both *per guest night* and per unit of GFA. This is in line with the findings of Tsai *et al.* (2014) for Taiwanese hotels but contradicts the evidence found in Spanish hotels (Puig *et al.* 2017). The potential reason for this gap can be in significant variations in the scope and scale of guest services provided by the hotels under study (such as the size of sports and business facilities, in-house restaurants and laundry) alongside differences in the frequency of their use. For example, in-house restaurants in Spain and Taiwan are traditionally popular with hotel guests while, in Iran, due to the cost factor, the use of on-site catering services may be limited. Likewise, conference facilities of luxury hotels are more likely to be used in Spain and/or Taiwan compared to Iran which may, again, be attributed to the affordability factor.

Table 6. CO_2 emissions of the surveyed hotels.

Analysis category	**Hotel A**	**Hotel B**	**Hotel C**	**Hotel D**	**Hotel E**	**Hotel F**	**Hotel X**
Annual CO2 emissions per guest night (kg/guest night/year)							
TOTAL	427 (100%)	225 (100%)	107 (100%)	-	182 (100%)	118 (100%)	38 (100%)
Electricity	74 (17%)	52 (23%)	68 (64%)	-	77 (42%)	41 (35%)	7 (18%)
Natural gas	353 (83%)	173 (77%)	39 (36%)	-	105 (58%)	77 (65%)	31 (82%)
AVERAGED	*212*						*38*
Annual CO2 emissions per unit of GFA (kg/m^2/year)							
TOTAL	276 (100%)	174 (100%)	247 (100%)	326(100%)	292(100%)	208(100%)	125 (100%)
Electricity	48 (17%)	40 (23%)	157 (64%)	75 (23%)	123 (42%)	72 (35%)	22 (18%)
Natural gas	228 (83%)	134 (77%)	90 (36%)	251 (77%)	169 (58%)	136 (65%)	103 (82%)
AVERAGED	*254*						*125*

Compared to hotels in other markets, the carbon performance of the studied hotels in Iran is poor (Table 5). Whilst the carbon intensity per unit of GFA finds some comparable figures in the context of Singapore (Xuchao *et al.* 2010), the value of CO_2 emissions the studied hotels generate *per guest night* is disproportionally high and cannot find any analogue in past research. The closest figure of 157 kg CO_2/guest night/year was recorded for luxury hotels in Taiwan (Hu *et al.* 2015) but it is almost 35% lower than the average value identified in this study. The range of figures reported in past research rests within the remit of 22-38 kg CO_2/guest night/year (Table 5) which is nearly 7 times less than the average value of the Iranian luxury hotels. Interestingly, the carbon footprint of the low-cost hotel in Iran (Hotel X, 38 kg CO_2/guest night/year) is higher than the range of figures reported for luxury hotels, let alone low-cost hotels, in other geographical markets, Table 5.

The main reason for this gap is the difference in hotels' popularity and the related low guest occupancy rates. For example, occupancy of 60-90% was reported for Taiwanese hotels (Tsai *et al.* 2014) and up to 100% for hotels in Spain (Puig *et al.* 2017). This is disproportionally high in comparison with the Iranian context where the figures of 15-37% were recorded. Lower hotel occupancy brings about higher carbon footprint (Becken *et al.* 2001; Filimonau *et al.* 2011a; Trung and Kumar 2005) which is well evidenced in this study.

A number of further reasons can explain the disproportionate discrepancy in carbon performance of luxury hotels in Iran and overseas. First and foremost, compared to the average values of carbon intensities of different fuels available for the UK (DEFRA 2019) and Taiwan (Tsai *et al.* 2014), the CO_2 emission coefficients for energy generation in Iran are significantly higher. For example, while 1 kWh of electricity generation produces an average of 0.64 kg of CO_2 in Iran (Iranian Ministry of Energy 2018-2019), the value of 0.25 kg of CO_2 is reported by DEFRA (2019). Likewise, the carbon intensity of natural gas in Iran is 4.89 kg/m^3 while DEFRA (2019) provides a figure of 2.02 kg/m^3. If the carbon coefficients used by DEFRA were employed in this study, the carbon footprint of the studied luxury hotels in Iran would decrease to an average of 102 kg/m^2/year and 75 kg/guest night/year and, thus, would create an impression of a better carbon performance compared to some Taiwanese hotels (Hu *et al.* 2015), for example. Having said this, even with this methodological adjustment, the carbon footprint of luxury hotels in Iran, when calculated *per guest night*, would still be excessive in comparison with other geographies, Table 5. This clearly shows that the higher carbon intensity of fossil fuels in Iran contributes disproportionately to the carbon footprint of hotel operations.

Second, unlike some of the Spanish 5-star hotels investigated by Puig *et al.* (2017), the Iranian hotels all operated at a full cycle and all-year-round and made in-house laundry available to their guests. The operational cycle of hotels and the presence of on-site guest services and amenities determine the magnitude of their carbon footprint (Castellani and Sala 2012; Filimonau *et al.* 2011b; Rosselló-Batle *et al.* 2010), which finds confirmation in this study.

Third, as mentioned earlier, the studied properties in Iran were less technologically advanced and less frequently retrofitted compared to their European and Asian counterparts which had an effect on their energy efficiency. Fourth, in Iran, there is currently no relevant legislation and/or government's guidelines on energy conservation and carbon audit which is in contrast to other countries, such as the UK, Australia and Taiwan (Lai *et al.* 2012). Fifth, the absence of international hotel chains in Iran suggests that the industry has developed no corporate policies and/or operational standards in energy and carbon reduction that other hotels could become familiar with and subsequently follow. This is in addition to the lack of non-governmental organisations and environmental activists in Iran that could impose some pressure on the industry in order to lobby the set-up of environmental conservation targets. Lastly, poor environmental awareness of domestic hotel guests in Iran suggests the industry does not have to listen to the environmental concerns of their customers while consumer feedback represents an important motivator for hotels to invest in energy and carbon reduction in other tourism markets (Legrand *et al.* 2017). Finally, Figure 3 summarizes measures that can be adopted in Iran to achieve better energy and carbon efficiency in (luxury) hotels.

Figure 3. Drivers of poor energy and carbon performance of Iranian luxury hotels and potential strategies towards how these can be addressed.

NATURAL	**EXTERNAL, NON-NATURAL**	**INTERNAL, NON-NATURAL**
Climate and geographical location	**Punitive economic sanctions**	**Institutional** / **Organisationa** / **Societal**
Thermal comfort Building adaptation to climate	Unfavourable country's image Interrupted flow of knowledge and capital	Poor, decentralised environmental and tourism governanc Over-reliance on low cost fossil fuels Environmental conservation is not a state priority
-Inadequate building design *-Inappropriate use of building materials* *-Unsuitable construction techniques* *-Unskilled construction workers*	*-Limited international tourism* *-Lack of internationally branded hotel chains* *-Lack of investment* *-Lack of novel technologies* *-Lack of technological 'know how'*	*-No environmental conservation targets* *-No diversified energy sources* *-Lack of corporate environmental awareness* *-Lack of environmental awareness among hotel guests with subsequent irresponsible behaviour*
-Errors in hotel building construction *-Mistakes in building planning* *-Questionable hotel building design*	*-Lack of pro-environmental corporate policies* *-Lack of environmental technologies* *-No pressure for hotels to go 'green'* *-Limited scope for retrofitting*	*-Lack of marked-based tools for energy conservation* *-Environmental management is not a corporate priority* *-No guest pressure on hotels to save the environment* *-No voluntary, pro-environmental industry agreements*
-Design for the environment -Exchange of good practices -Expert consultancy -Foreign expertise and experience	-Pro-active destination marketing -Incentives for international hotel chains -Liaised exceptions to sanctions for the transfer of environmental technologies and 'know how'	-Clear energy conservation and carbon reduction targets -Financial (dis)incentives for (non-)compliance -Databases of benchmarking data on energy use in hotels -Environmental management training for hoteliers -Public environmental awareness building campaigns
-Building and construction legislators -Hotel management -Scholars (architects and engineers)	-Policy-makers -Destination management practitioners -Industry associations	-Policy-makers -Hotel management and industry associations -Environmental and tourism NGOs -Scholars (social scientists) -Media

5. Conclusions

The study made a number of theoretical and empirical contributions. From the viewpoint of theory, it provided further evidence to how the method of LCEA can be applied in the hotel sector to assess the energy and carbon performance of tourist accommodation facilities. With a case study of luxury hotels in Iran, this project has proven the scientific rigour and shown the cost-effectiveness of LCEA as a means of understanding the energy and carbon footprint of tourist accommodation. From the empirical perspective, the study provided a first known benchmark of energy consumption and carbon footprint of luxury hotels in Iran, a large Middle East's economy with continuously developing tourism. The study revealed exceptionally high energy and carbon intensity of luxury hotels in Iran when compared to their counter-parts located in other tourism markets. The study further showed a substantial discrepancy in energy and carbon performance of luxury and budget hotels in Iran and outlined the reasons for its occurrence.

The disproportionate energy and carbon intensity of luxury hotels in Iran calls for urgent mitigation measures. The development of these measures should engage multiple stakeholders as manifold factors were found to influence the inadequate energy and carbon performance of Iranian hotels. As a key stakeholder, Iranian policymakers should, at foremost, attempt at easing/lifting the punitive economic sanctions to provide hoteliers with access to the international 'know how' and modern energy conservation technology. They should further set energy conservation and carbon reduction targets for the hotel sector and design a range of market-based tools encouraging Iranian hotels to meet these targets. For example, no/low interest loans can be made available to hoteliers for the adoption of the Building Management Systems (BMS) and Computerised Maintenance Management System (CMMS). Example of Hotel F reviewed in this study showcases the importance of such solutions in the more effective energy management in hotel properties. Renewable energy technology, particularly solar, should also be actively promoted among hoteliers given the abundance of sunshine in Iran. Another stakeholder, the Iran Hotel Association, should establish and regularly update a free-to-access database of benchmarks on energy use and carbon emissions for Iranian hotels. This database can stimulate awareness of hotel administrations of the problem of excessive energy use and enable comparisons across hotel properties, thus prompting hoteliers towards energy conservation. The Iran Hotel Association, in cooperation with the Iranian Department of Environment or the Iranian Ministry of Energy, can further provide hotels with relevant guidelines and standards on how to monitor/audit energy use in hotel buildings. Lastly, it can organise hands-on trainings and invite industry experts, from Iran but also from abroad, to demonstrate the benefits of energy reduction and share good business practices in how it can be achieved. Hoteliers, as another stakeholder, should, as a bare minimum, start monitoring energy use in their properties on a regular basis and develop measures encouraging its conservation. In particular, they should encourage hotel guests to save energy by raising their awareness but, also, by incentivizing energy saving behaviour.

As for the limitations of this study, first, the sample was restricted to the highest comfort level of hotels in Iran. As mentioned earlier, this choice was deliberate and, to a large extent, unavoidable given that the energy data essential for this project were treated with complete confidentiality by many Iranian hoteliers. Therefore, sector-typical luxury hotels, deemed to be leading the hotel sector in its progress towards the goal of environmental sustainability, made up the sample of this study. Second, the lack of primary data inventories relating to the non-operational energy and material use of the surveyed hotels hampered this study's initial intention to conduct a 'traditional' LCA, i.e. accounting for the instances of 'indirect' energy and material flows in hotel properties and considering a range of environmental impacts. Such a full-scale study would be more comprehensive, albeit exceptionally laborious and, potentially, expensive should, for example, the missing primary data inventories were procured from a commercial provider.

A number of directions for future research can be outlined. The benchmarks of energy and carbon performance established by this study for Iranian luxury hotels can prompt future research to assess the energy and carbon efficiency of other hotel categories in Iran, especially those from one-/two-/three-star classes that dominate the market. Future studies should also attempt at quantifying the non-operational energy use in different hotel categories. By combining non-operational energy with the benchmarks of operational energy consumption established in this study, future research will provide a more holistic understanding of the energy use and carbon footprint patterns in Iranian hotels. Lastly, given the importance of multi-stakeholder involvement in conserving energy in hotels in Iran, the perspectives of such stakeholders as policy-makers, industry representatives, environmental activists and hotel guests should be sought by scholars on how the environmental sustainability agenda can be more actively promoted among Iranian hoteliers.

Declaration

The authors hereby declare no conflict of interest

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