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A Review: Urban Heat Island and its Impact on Building Energy Consumption

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ABSTRACT

Civilization and urbanization are the two key demands of humans in the 20th century. Over the last few decades, a considerable number of the human population have moved to urban areas. This phenomenon has led to an explosion of the population in some of the major cities around the globe, including in Saudi Arabia. Urban Heat Island (UHI) is a climatic condition in which urban settlements experience increased air temperature than their neighboring rural counterparts. The UHI is attributed to the anthropogenic modification of land surfaces, population growth, urban development, and its consequential production of waste heat, which is endangering human health and the environment as well as the quality of living. Series of factors have been responsible for UHI, including building orientation, material albedo, land use, high-rise constructions, and human activities. The present study investigates the significance of the UHI features and their relation to building energy consumption. A list of contributing factors to UHI was identified and analyzed. The study suggests that there is a positive relationship between urban greening and urban material concerning energy consumption. Thus, this is a potential study gap that needs to be addressed to analyze the impact of UHI, particularly in the context of Saudi Arabia.

Keywords: Urban heat island; energy consumption; environment; buildings

INTRODUCTION

Urban Heat Island (UHI) can be defined as a climatic phenomenon whereby adverse effects of human activities such as deforestation, urbanization, population expansion, and generation of greenhouse wastes cause the air temperature to be higher in the urban settlements than their rural counterparts (Parvez et al. 2021). The UHI effect is of great concern due to the rapid increase in the urban population, which increases the demand for amenities such as housing, roads, and other infrastructures. The peak energy consumption is due to population density and human behaviours, all of which contribute substantially to UHI (Kolokotroni & Giridharan 2008; Kolokotsa et al. 2009; Shahmohamadi et al. 2011; Ghazanfari et al. 2009). A United Nations report shows that between 2010 and 2020, more than 60 million inhabitants have moved to metropolitan areas in Africa, Asia, Latin America, and other countries (Tacoli et al. 2015).

Several factors may lead to warmer urban climate, such as dark surfaces, deforestation, shortage of green zones, minimized infrared radiance to the atmosphere due to trapping of emission by urban complex, and low movement of air in the dense metropolitan areas (Oke et al. 1991). UHI is developed mainly in metropolitan areas with a higher ratio of water resistance, non-reflective surfaces, and reduced vegetation, thus making urbanization and thermal behaviour of the urban built environment the two major factors in the formation of UHI (Coccolo et al. 2018). One of the significant consequences of these human activities is climate change; fifteen of the warmest years in the world's history were recorded in the past seventeen years (Silvero et al. 2019). This was attributed to the impact of increased carbon and GHG emissions, thereby leading to global warming. The years between 1880-2012 recorded a temperature of 0.65 to 1.06 °C in the average of combined land and ocean surface temperature. The result of the worst-case projection forecasted that this figure might likely increase by 2.6–4.8°C in the years between 2081 to 2100 compared to figures recorded from 1986 to 2005 (Silvero et al. 2019). Urbanization has been a crucial element for radical changes in the land surfaces and atmospheric conditions at the regional to the local level by removing natural material and replacing them with non-evaporating and non-transpiring surfaces (Amirtham et al. 2009; García Cueto et al. 2009). The average daytime temperature in urban settlements may increase by about 8-10°C due to road surfaces (concrete or asphalt), building walls, or paved surfaces (Arifwidodo & Chandrasiri, 2015). In Bangkok, for instance, it was found that the difference in urban heat island intensity (UHII) between selected rural and urban areas is 3.5 °C (Boonjawat et al. 2000).

In a recent study, it was stated that the urban population and urbanization in KSA has almost reached 85% (Abubakar & Dano 2020). This high urbanization rate was a good motivation for spatial expansions in the major Saudi cities. In the period between 1985 – 2000 and 2000 -2015, the special expansion was recorded to manifest 40% and 50%, respectively (Alqurashi et al. 2016; Aina et al. 2019). As a result of both the high urbanization rate and spatial expansion, several analytical kinds of research have suggested that there is a remarkable temperature increase around KSA, especially in the maximum temperature (Hereher, 2016; Rahman et al. 2017; Howarth et al. 2020a). For instance, in an international study, the Surface UHI was shown in KSA cities, including Jeddah, Dammam and Riyadh, to be 0.43, 0.04 and 2.6, respectively. Remarkably, based on Surface UHI, Riyadh city was ranked the 15th in comparison with more than 70 other urban settlements. Simultaneously, both minimum and maximum air temperature, including summer and winter seasons in Jeddah city, have minimally increased by 2°C in the period between 1986-2016 (Parvez et al. 2021). In a similar study, the average temperature in Dammam city has been shown to increase from 36.42°C to 44.12°C in 1990 and 2014, respectively (Rahman et al. 2017). The effects of UHI have significantly contributed to health hazards (Ye et al. 2021). In cities such as Hong Kong, Delhi, and Bangkok, every 1°C rise in temperature above 29°C raises the mortality rate from 4.1% to 5.8% (Chan et al. 2012)a major city in China, has one of the world's highest income inequalities and one of the world's highest average increases in urban ambient temperatures. Heat-related mortality in urban areas may vary with acclimatisation and population characteristics. This study examines how the effect of temperature on mortality is associated with sociodemographic characteristics at an intracity level in Hong Kong, China, during the warm season. Methods: Data from the Hong Kong Observatory, Census and Statistics Department, Environmental Protection Department and government general outpatient clinics during 1998e2006 were used to construct generalised additive (Poisson. The Canadian health Ministry stated that with each degree rise in the air temperature in the seven largest metropolitans, per diem temperature above 20***°C***, leads to a consequent increase in the mortality rate by 2.3% (Smoyer-Tomic & Rainham, 2001). According to-research conducted in the Netherlands from 1979-1999, it was reported that with every one-degree increase in air temperature beyond the optimal level, the mortality rate increased by 2.72%. These facts show that an increase of 2–3◦C leads to a 4–7% rise in the death rate in Canada and 5–8% in the Netherlands (Huynen et al. 2001).

This paper aims to review the literature on the contributing factors to UHI and its relation to building energy consumption. The paper further focused on the context of Saudi Arabia by reviewing the status of three main parameters related to UHI viz population and growth of the housing sector, expansion of energy consumption, and review of the highlighted UHI studies within Saudi Arabia context.

FACTORS CONTRIBUTING TO THE FORMATION OF UHI

URBAN THERMAL PROPERTIES

In the process of urbanization, the used anthropogenic materials enhance heat storage by combining thermal conductivity and heat capacity (Gartland, 2008; Kaloush et al. 2008). These properties interact in two different ways; the higher thermal conductivity of anthropogenic materials promotes heat conduction to a large extent, while materials with high heat capacity promote heat storage in their volume. A major parameter to evaluate material efficiency is albedo. In the field of climate research, remote sensing, and atmospheric, the notion of albedo is associated with energy balance at all spatial and temporal scales, from a single pixel in aerial monitoring to a global scale. In solar approaches, the definition is primarily based on estimating emission from specific solar collectors (Duffie et al. 1985; Liu & Jordan 1963). In general, anthropogenic materials usually absorb higher net radiation than natural materials because they possess low solar reflectivity, described as the proportion of surface-reflected emissions to the total amount of radiation received by that surface (Strugnell & Lucht 2001). Typically, whenever the material is characterized by a lighter colour, the albedo value increases. Consequently, a high amount of solar radiation could be reflected; thus, the surface temperature is decreased, and vice versa.

Albedo is a measurement of the reflected solar capacity for a specific surface and it is estimated on a scale of 0 to +1, where higher values indicate brighter and highly reflective surfaces, while lower values indicate darker and duller surfaces. For instance, a material with an albedo of 0.10 tentatively absorbs about 90% of incident sunlight, resulting in the material having a very hot surface (Ban-Weiss et al. 2015). Thus, the material can be used to determine the rate of reflection or absorption of solar radiation and heat. In-neighborhood-scale research conducted in Sydney, the use of 0.4 global albedos led to a reduction of 1***°C*** in the ambient temperature (Santamouris et al. 2018). However, in cooler regions, warmer daytime temperatures may promote outdoor activities, reduce the damage caused by frost (Yang & Bou-Zeid 2018) enhance the development of urban eco-space construction (Igor et al. 2016).

Since Asphalt Concrete (AC) occupies a large part of the urban area, it is essential to understand the thermal conductivity of different types of AC to enhance the UHI consequences. The typical black color AC coating areas are characterized by higher temperatures (Bobes-Jesus et al. 2013; Doulos et al. 2004). This arises due to the comparatively low albedo of AC and its' characteristic thermal absorption and conductivity properties as compared with other pavement materials (Higashiyama et al. 2016; Santamouris, 2013; Doulos et al. 2004; Bobes-Jesus et al. 2013). Due to their inherent properties, asphalts can absorb a significant amount of solar radiation and release the trapped radiant heat stored in the atmosphere during the night. In a comparison of the effect of different pavement covering on urban temperatures, it was stated that apart from the influence of material colors on heat gain, the texture of material also plays a vital role in heat gain. Notably, there is a significant difference in surface temperature between two white-colored materials with different textures (Asaeda et al. 1996).

URBAN GREENING

Several studies have indicated that the presence of vegetation in cities would improve the micro-climate measures, such as air temperature, relative humidity, wind velocity, and rainfall (Byrne et al. 2008). Therefore, vegetation in the urban area has been proposed as an essential adaptation measures and vital means of reducing the UHI phenomenon and health-related effects of high environmental temperatures (Givoni 1991; Gill et al. 2007; Byrne et al. 2008). In rural areas, the landscape is comprised of vegetation and open spaces. The shading effect of trees and vegetation decreases the surface air temperature by evapotranspiration. In contrast, built-up areas are described as dry areas due to a decrease in water evaporation. However, this is considered to be insufficient for impervious urban surfaces, which instantly retain and absorb solar radiation. A decrease of 3.1 °C in ambient temperature due to evapotranspiration alone was reported in Chania (Georgi & Dimitriou 2010). In hot and dry climates found in mid and low latitudes, evapotranspiration has a greater impact on reducing the ambient air temperature, resulting in the formation of 'oases' that are 2.0-8.0°C cooler than their adjacent environment (Taha 1997). Similarly, studies on 11 wooded areas in Tel-Aviv showed that 80% of the cooling effect was due to tree shades (Shashua-Bar & Hoffman 2000).

Vegetation in urban areas is often limited to parks and recreational spaces, and the effect of tree shades on structures in their immediate surroundings is referred to as Park Cool Island (PCI). Daytime PCIs may arise under adequate irrigation due to the effects of soil moisture, trees shading, and grass-evaporative cooling. Peak intensity of daytime PCIs occurs at noon (forest type) or in the evening (garden type). Conversely, night-time PCIs are triggered by longwave radiative cooling by developing relatively dry urban parks with dispersed tree arrangements. In a hot and dry climate, a park with an area of 0.15 Hectares (0.37 Acre) had an average cooling effect of about 1.5°C, which at noon can reach up to 3.0°C (Shashua-Bar & Hoffman 2000). As a result of variations in the expanse and configuration of urban vegetation, the PCI effect is highly variable. Forest parks in Florida were found to be cooler than nearby areas with extensive vegetation, which in turn was cooler than the less-vegetated neighborhoods (Jamei et al. 2016). The result indirectly agrees with the previous study, which reported that the extent of the hard surface cover was responsible for about 70% of the increase in land surface temperature (Imhoff et al. 2010. Research by Jamei et al. (2016) indicated that cooling extends almost towards the width and beyond the boundaries of a park, and it may extend up to 1 to 2 km in larger parks. During intense sunshine, the evapotranspiration effect of one tree has a cooling effect that could be compared to that of 10 air-conditioning units with a total power of 20-30 kWh (Kleerekoper et al. 2012). Nevertheless, grasses reduce temperature primarily by evapotranspiration at ground levels without affecting direct incoming radiation, whereas trees lower ambient air and surface temperatures by optimizing the presence of shading, thereby reflecting solar radiation in the atmosphere (Rahman et al. 2015; Tsilini et al. 2015).

ANTHROPOGENIC HEAT

The human-induced heat emission is a major factor contributing significantly to effect of UHI due to its direct impact on the metropolitan environmental temperature (Oke 1988; Rizwan et al. 2008). As stated by Intergovernmental Panel on Climate Change IPPC, it was estimated that human-induced climate change would increase surface air temperature between 0.5°C - 6.5°C over the next 100 years (Sailor and Lu 2004). Human-induced urban heating is attributed to three main agents, which are; vehicular traffic, buildings, and human metabolism (Smith et al. 2009). In the United Kingdom, the proportional split of these three sources suggests that the building sector is the leading emitter of heat, accounting for over 60% of the total anthropogenic heat flux (Quah & Roth 2012). A study in Singapore revealed that buildings were the key contributor to anthropogenic heat, accounting for 83% and 54% in commercial and residential areas, respectively (Landsberg, 1981). On warmer days, heat from lighting, home appliances, and human metabolism are removed from the building by a cooling system condenser to keep the interior at a convenient temperature. The dissipated heat is discharged to the atmosphere at different rates based on the position of the system (roof or walls). The discharged heat increases the outdoor temperature, thus promoting the UHI effect.

In New Jersey, the contribution of human metabolic heat increased from 2.6% to 4.2% (Cox, 2014). A similar study on the distribution method for estimating spatial variation in anthropogenic heat uses the spatial classification method for estimating the effect of anthropogenic activities. The result of the research showed a significant change in the anthropogenic heat concentration of the Yangtze River Delta region, located in southeast China with urban agglomeration and human activities. From the comparison of different cities, the greater impact of anthropogenic heat inflow into the urban zones has been recorded in areas generating enormous anthropogenic heat emissions (He et al. 2020). Furthermore, depending on the season, the relationship between the yearly mean anthropogenic heat emissions and the spatial pattern of urban settlement during the summer, is more significant compared to the winter season (Dhakal et al. 2003).

In residential areas where the use of electrical devices could be of great value, anthropogenic heat is higher, resulting in changes in the ambient air temperature. The air-conditioning system of a building consumes the most substantial proportion of electricity demand, resulting in indirect influence on the urban thermal environment via the discharged of heat accrued in the interior of the building to the atmosphere to attain indoor thermal comfort (Hsieh et al. 2011; Roth & Chow 2012).

URBAN HEAT ISLAND AND ENERGY CONSUMPTION

Several analyses have reported the adverse effects of UHI on the energy performance of buildings. In a recent review, Santamouris (2014) analyzed the UHI, which was evident from an increase of 11% in annual energy demand (23% for the cooling pad) (Santamouris, 2014). In the relation between UHI and energy consumption, it was argued that a 1°F increase in ambient air temperature would result in an annual increase of 5-10% in peak energy demand (Gray & Finster, 1999). In similar research, the energy demand for cooling an office building in central Athens metropolis is reported to be twice as high as that required for the cooling of a similar building in the countryside~~,~~ and thrice the loads for the peak energy duration. The study further revealed that urban constructions consume 13% higher cooling energy compared to buildings in rural areas (Santamouris 2014). On the other hand, UHI can be a positive phenomenon in cold regions as it reduces ~~the~~ heating consumption. In Greece, the energy required for heating in buildings could be reduced by about 50% in urban areas (Asimakopoulos et al. 2012). Similarly, the summer and winter energy consumption for cooling and heating of exemplary office buildings in Athens, Greece using weather reports from thirty meteorological stations found that in the central area, energy used for cooling and heating is 120% greater and 38% lesser respectively, compared to the rural reference point (Santamouris et al. 2001). The energy use by the air conditioners in a Mediterranean residential apartment was analyzed based on five provinces located on the west of Athens. The results showed a 67% and 29% increase in energy consumption in urban housing compared to the sparsely populated areas in 1997 and 1999, respectively (Hassid et al. 2000).

In Osaka, Japan, a 22% increase was recorded in cooling energy demand for buildings in an urban environment, while a 33% decline was observed in heating energy demand is estimated to fall by 33% (Shimoda et al. 2004). In a similar study in London, an analysis of building energy consumption based on information from 20 meteorological stations revealed that energy use for cooling is 27%–45% higher while heating energy demand in urban areas is 64% lower than the rural areas (Kolokotroni et al. 2007). In a study conducted on global warming influence on UHI and energy consumption of the building, it was found that cooling demands in urban buildings are about 13% higher than in rural buildings. In the same study, the difference in energy use from 1970–2010 were analyzed to recognize the impact of global warming on building energy consumption. The result indicated that energy demand has increased by 23% while heating has decreased by 19% (Santamouris et al. 2015).

In numerical research, modeling for the investigation of meso and micro climates and their relevance to the energy consumption of buildings was done by using a single-story residence building prototype made up of wood-frame. It was established that a 25% increase in vegetation, specifically tree elements, conserves about 40% of the cooling energy consumption in the residential sector in Sacramento, CA, compared to 25% in Phoenix, AZ, and Lake Charles, LA (Huang et al. 1987). Similarly, a modeling approach on multiple cities in Canada examined the notion of shading structures in neighbourhoods, considering construction and trees of varying dimensions, expanses, and orientations. The result showed a 36% reduction in cooling energy consumption while heating energy consumption was increased by only 1.2% (Nikoofard et al. 2011)distance and size of the neighbouring object on heating and cooling energy requirement are investigated for four major cities (Halifax, Toronto, Calgary, Vancouver. In a similar simulation approach to analyze the impacts of reflective surfaces and trees in multiple Canadian cities. It was found that about 30% increase in vegetation could result in over 10% and 20% reduction in cooling energy demand in urban houses and rural dwellings, respectively. The findings further revealed that when the albedo is increased by 0.2, changing the material colors from dark to light reduces the energy used for cooling by 30–40% (Akbari & Taha 1992).

UHI AND SAUDI ARABIA

POPULATION AND GROWTH OF THE HOUSING SECTOR IN SAUDI ARABIA

The population of Saudi Arabia has been on a rapid increase since the last decade. As shown by the General Authority for Statistics (GASTAT 2019), the population recorded over 27 million residents in 2010 (Alrashed & Asif 2014). With a growth rate of 2.57, the population increased to reach 34,218,168 in 2019 (General Authority for statistics, 2021). The resultant effect of the increase in population results in higher demand for housing. It was projected that by 2019, the country will record an increase of nearly seven hundred and fifty thousand households, and about 2.32 million additional houses will be required to cater for these populations (Alshaikh 2016). In a recent survey conducted by GASTAT, it is shown that the total number of dwellings occupied by Saudi households increased by approximately 100,000 between 2017 and 2018 (GAS 2018).

Nearly 90% of dwellings in Saudi Arabia are built with concrete materials (Figure 1), which is considered a high contributor to UHI (Ahmad 2002)commercial and governmental buildings besides the increased costs of energy required for heating and cooling. In this paper, the main insulation materials and types of walls structures used in residential buildings in Saudi Arabia are discussed. Then a systematic approach for optimization of insulation materials thickness, payback period and cost analysis for different wall structures is developed and applied to two main cities in Saudi Arabia (Riyadh and Dammam. Nearly £1.8 billion of the government surplus budget has been set aside for the housing program (Alshaikh 2016). The Ministry of Housing indicated that the number of beneficiaries of the housing program reached 85,928 in 2020. This figure shows an increase of about 17% in the housing sector compared to 2019 (Ministry of Housing, 2020). Table 1 shows housing unit types that are occupied by Saudi households.

Meanwhile, there was a remarkable increase in population growth in the urban settlements in Saudi Arabia, with more than 66% population increase recorded in the urban settlements of the country between the years 2000-2017. The urban and rural population of the country between 1960-2019 is presented in Figure 2. However, in comparing the percentage of the urban population in Saudi Arabia and the United States, it was recorded that the urban population growth percentage in Saudi Arabia exceeds those recorded in the United States as shown in Figure 3 (Ritchie and Roser 2018; Mohammed Abdullah. Bakarman 2017).

TABLE 1. Number of Dwellings (Occupied with Saudi Households) by Type of Dwelling

Administrative region	Villa	Apartment	Traditional Dwelling	Floor in villa
Al-Riyadh	395560	288360	48160	131672
Makkah Al-Mokarramah	117827	576285	183876	21090
Al-Madinah Al-Monawarah	37341	151575	60840	2604
Al-Qaseem	97980	15100	25857	31992
Eastern Region	176118	253116	57770	30628
Aseer	112326	111972	57312	32512
Tabouk	8379	78174	38055	1222
Hail	34675	14241	31825	3564
Northern Borders	16500	10842	6552	4698
Jazan	33864	32560	103649	11970
Najran	18018	28032	22411	4100
Al-Baha	24089	29232	14056	5248
Al-Jouf	22560	20919	14628	2788
Total	1095237	1610408	664991	284088

Source: General Authority for Statistics 2019

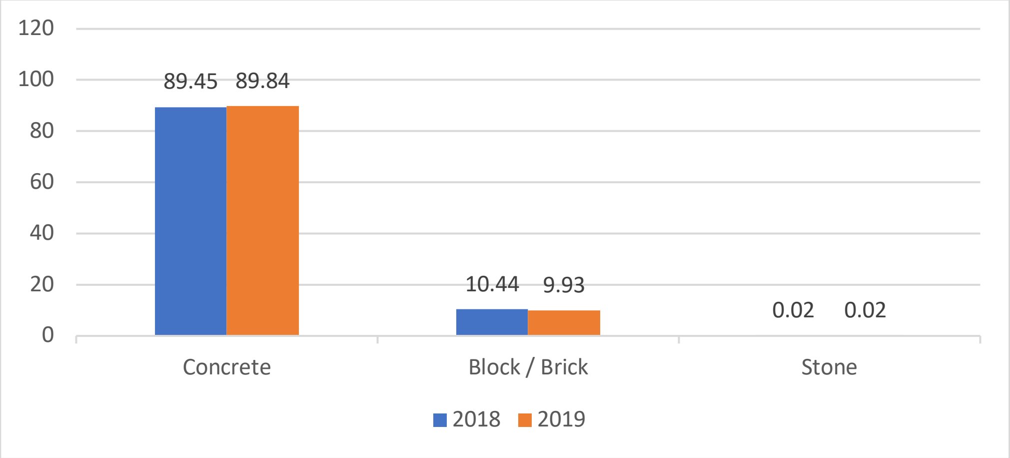

FIGURE 1. Percentage distribution of total of housing units (occupied with Saudi households) according to construction types (2018-2019) (GASTAT 2019)

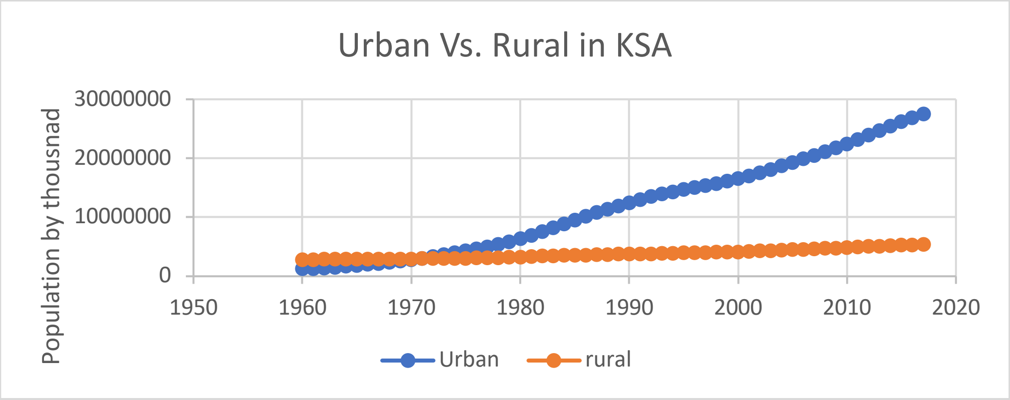

FIGURE 2. Urban Vs. Rural Population growth in KSA (Ritchie & Roser 2018)

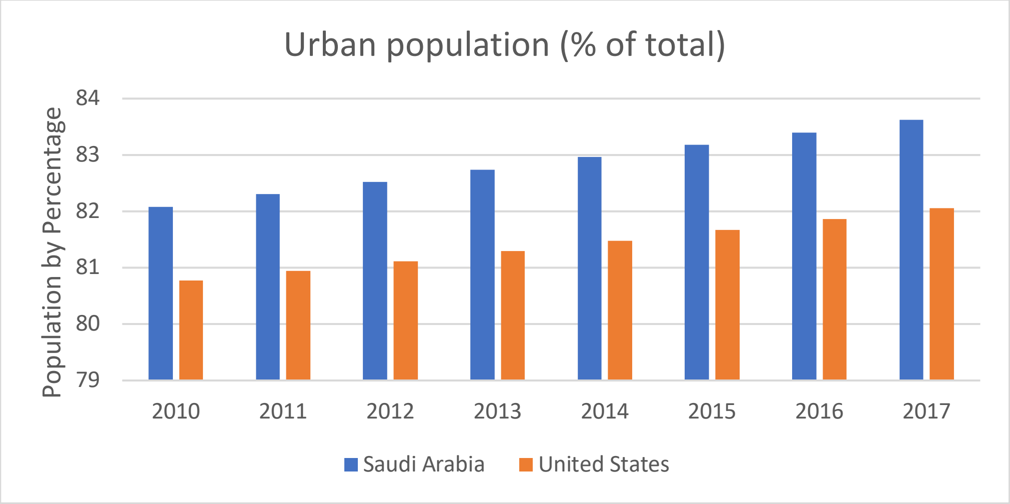

FIGURE 3. Saudi Arabia Vs. USA Urban population growth (Ritchie & Roser 2018)

EXPANSION OF ENERGY CONSUMPTION IN KSA

Due to the rapid increase and development in KSA, an annual average increase of 13% of energy consumption in buildings has been reported (Fasiuddin & Budaiwi, 2011; Hussin et al. 2019)there has been a dramatic increase in energy consumption in Saudi Arabia. The building sector being the largest consumer of electric energy represents a major potential contributor for reducing energy consumption. Due to their functional and operational characteristics, commercial buildings relatively consume more energy (per unit area. In the Islamic capital of Saudi Arabia (Makkah), the total electricity consumption between 2009 -2018 increased from 65.292 gWh to 101.159 gWh which is considered the highest energy consumption increase among regions in the country (GASTAT, 2019). Referring to the Electricity and Co-generation Regularity Authority (ECRA), the residential sector accounts for approximately 44% of the total energy consumption (Figure 4). Besides, in KSA, it was presented that the residential and commercial sectors account for the highest share in terms of total construction permits issued in 2015 by the building sector (Figure 5).

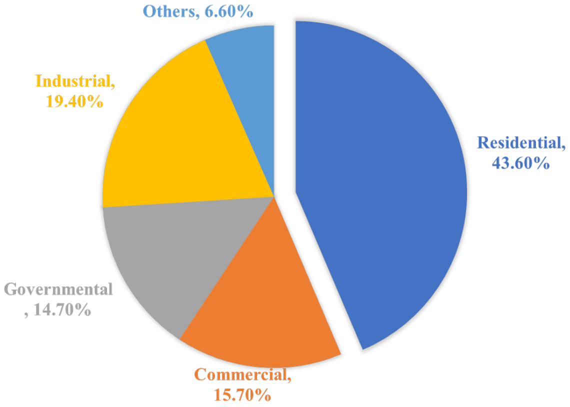

FIGURE 4. Percentage of energy use per sector in KSA in 2018

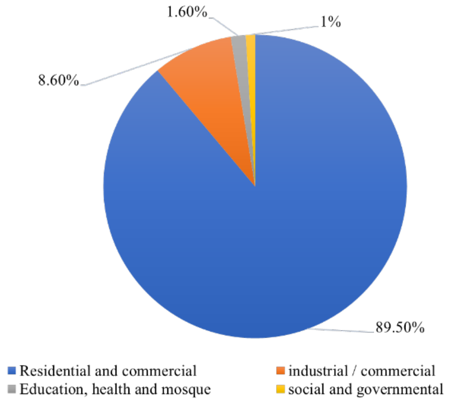

FIGURE 5. Construction permission for buildings in Saudi Arabia in 2015

Table 2 shows a list of research related to UHI examination in KSA. From the previous studies, two cities viz Riyadh and Jeddah have been shown to gain the interest of researchers as case study areas. Simultaneously, most of the studies used the Landsat images methods to retrieve LST data and compare it to surrounding rural populated areas. The main purpose of selecting the Landsat images is their ready availability as a source of metrological information. However, when exploring UHI, the archiving of the micro-weather metrological parameters must explain the actual characteristics of a given area, and this is argued to be hard to accomplish via Landsat images (Kotharkar et al. 2018). Also, there is invariably a probability of cloudy sky when the satellite images capture the UHI over a land. In addition, the measured surface temperature can be significantly different from the ambient air temperature measured through field measurement in which turbulence and velocity activities impact the ambient air temperature (Mirzaei & Haghighat 2010).

TABLE 2. Review of the UHI studies in the last decades within the Saudi Arabia context.

Title	Location	Metrological parameters	Methodology of measuring metrological parameter	Reference
Spatiotemporal Variations in the Impacts of Urban Land Use Types on Urban Heat Island Effects: the Case of Riyadh, Saudi Arabia	Riyadh	LST	Landsat images	(Aina et al. 2017)
Evaluation of the urban heat island over Abha-Khamis Mushait tourist resort due to rapid urbanisation in Asir, Saudi Arabia	Abha- Khamis Mushait	LST	Landsat images	(Arshad et al. 2021)
Spatial-temporal variation of the land surface temperature of Jubail Industrial City, Saudi Arabia due to seasonal effect by using Thermal Infrared Remote Sensor (TIRS) satellite data	Jubail	surface temperature	Landsat images	(Sheik Mujabar, 2019)
The Influence of Height/width Ratio on Urban Heat Island in Hot-arid Climates	Riyadh	Air temperature Surface temperature	In site measurement	(Bakarman & Chang, 2015
Spatiotemporal assessment of air quality and heat island effect due to industrial activities and urbanization in Southern Riyadh, Saudi Arabia	Riyadh	LST Air quality parameters	Landsat images Air quality station	(Salman et al. 2021)
Utilizing remotely sensed observations to estimate the urban heat island effect at a local scale: A case study of a University campus	Jeddah	LST	Landsat images	(Addas et al. 2020)
Examining and modelling the determinants of the rising land surface temperatures in Arabian desert cities: An example from Riyadh, Saudi Arabia	Riyadh	LST	Landsat images	(Rahman, 2018)
Cool white marble pavement thermophysical assessment at Al-Masjid Al-Haram, Makkah City, Saudi Arabia	Makkah	Air temperature Wind speed	Weather stations	(Alghamdy et al. 2021)

CONCLUSIONS AND FUTURE WORK

The study reviews the research on UHI and its relation to energy consumption and various parameters contributing to UHI formation were discussed. The study detailed the influence of UHI on energy consumption with consideration for the role of different UHI forming parameters on energy consumption. The status of Saudi Arabia in terms of increased population, housing, and energy consumption were also highlighted. It was concluded that the thermal properties of materials in an urban context, vegetation, and greenery can be used to mitigate the impact of UHI on building energy consumption. In addition, it was observed that there is a dearth of UHI studies in the context of Saudi Arabia that includes ŧ on-site measurements rather than Landsat images which was mentioned as inefficient for accurate estimation of the UHI situation.

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DECLARATION OF COMPETING INTEREST

None

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