Journal of Advanced Engineering Trends
ISSN : 2682 - 2091

Vol.42, No.1. January2023

http://jaet.journals.ekb.eg

Ecological Urban System in GCC Countries: Potentials, Obstacles and Actions

ASHRAF MOHAMED SOLIMAN
Associate professor at Kingdom University, Bahrain and Mina University, Egypt
a.soliman@ku.edu.bh
arcgroupfec@gmail.com
arcgroupfec@icloud.com
Address: Building P.O. Box 40434,
Kingdom of Bahrain – Riffa
Building 287, Road 3903, Block 939

Abstract:

The urban system consists of six main components: urbanism level, land cover, urban tissue, urban governance, consumed energy, and natural resources. Those components are addressing in different approaches depending on historical, cultural, demographical, architectural, geographical, and economical characteristics of the urban system. History and culture usually play the main role to put the settlements in a specific urbanism level; (i.e. highly urbanism as urban cities or lowly urbanism as rural villages). The more prosperous countries can make ecological urban systems for all their urban settlements. This approach is not only easy to implement in the countries that have natural resources, but also the country that is in an advanced phase of development. Solar and wind energy are the main ecological energy, particularly in the GCC (Gulf Cooperation Council) countries. "GCC countries endowed to build the ecological urban systems with renewable resources." Renewable energy is one of the advantages of the geographic characteristic of those countries. Urban tissue, mainly the urban form and urban space pattern are specified by the architectural characteristic which affects the ecological system positively and negatively. The impact of urban tissue accrues according to the design of buildings and planning of the cities. In addition, the demography is playing a key role in urban tissue and land cover which come in the early listed components of the urban system. Therefore, this research explores in depth of the sophisticated map of the ecological urban system, in order to come out with principles of producing an ecological urban system in GCC countries. The author used secondary, subjective and descriptive research approaches, in which a theoretical background has explored the ecology and urban system components with their addressing characteristics to find out the relationship in between them. A SWOT analysis study of resources and potentials have been carried out to explore the strengths, weaknesses, opportunities and threats of developing an ecological urban system in GCC countries. This research has been ended with the main results of the analysis, which are formed as recommended actions to be taken by concerned authorities to develop a comprehensive ecological urban system.

Keywords: Ecological, Urban system, GCC.

1. Introduction:

Many municipalities around the world aim to adapt the urban system to enhance urban efficiency. They use technology as a powerful mean of achieving carbon neutrality and developing an ecological urban system. Nevertheless, developing environmentally sustainable cities with technologies' capacities needs to be supported by integrated cultural, social, educational and environmental policies and procedures. Such policies and procedures develop and manage the relevant ethical knowledge, skills, attitudes and behaviors of peoples towards the sustainability to sustain the quality of the built environment [1].

This paper argues that ecological urban system is an integrated system of urban planning compiles balanced urbanism level of the settlement, maintained green land cover, appreciate urban tissue, centralized governess organization, controlled energy consumption, and suitable energy resources. Those six components are affected by different factors that depend on historical, cultural, demographical, architectural, geographical, and economical characteristics of the urban system as shown in figure 1.

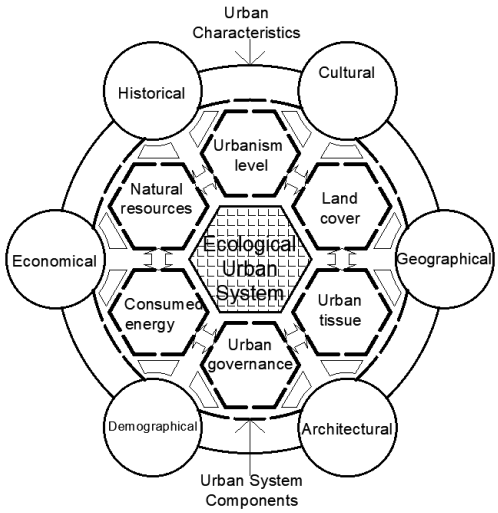


Figure 1: Urban system components and their relative characteristics

The cultural characteristics through history has impacts on the urbanism level of any communities; the peoples' activities need a specific urban style and level of the settlement. "*Countries that are highly urbanized have higher incomes, more stable economies, stronger institutions and are better able to withstand the volatility of the global economy than those with less urbanized populations"* P.134 [2] Geographical location and culture of land uses changes affect the land cover status. changing land uses from agricultural to urban uses reduce the green features of land cover, specially in the arid and desert zones. Architecture in different geographical regions forms the urban tissue. The architects consider the project's site context to achieve building workability and sustainability, create mobility options, develop multi-use spaces, and create ecological systems. They aim to promote the public health with happiness, increase personal choices, support sustainable lifestyle, and optimal utilization of natural resources [3]. Architecture also has ten characteristics to be alive, most relative to the ecological urban system are greenery, water's feature and natural light in the buildings [4]. Urban planning authorities and municipalities manage the urban and suburban development to fulfill the needs of all populations' categories. Number and characteristics of populations determine the demanded energy. Population has direct proportionality to the demanded energy, but energy consumption has inverse proportionality to energy cost. Therefore, solar and wind energy are the main ecological energy, particularly in the GCC region, "GCC countries endowed to build ecological urban systems with renewable resources. *They benefit from strong regular sunshine, and the space to develop large solar power plants. The region also has significant wind resources, geothermal and biomass from urban waste."* [5]. This benefit of renewable energy; especially solar energy is one of the advantages of the geographic characteristic of those countries. Culture of energy combustion and economy level of the country affect the optimal utilization of the natural resources, due to required high primary cost technologies for ecological systems, the more prosperous countries are more able to establish ecological urban systems for all their urban settlements. This approach is not only easy to implement in the countries that have natural resources, but also the country is in an advanced phase of urban development.

Received:29 October, 2020, Accepted:5 April, 2021

2. The research methodology:

The author uses secondary, subjective and descriptive research approaches, in which a theoretical background has explored the ecology and urban system components with their addressing characteristics to find out the relationship in between them. A SWOT analysis study of resources and potentials have been carried out to explore the strengths, weaknesses, opportunities and threats of developing ecological urban system in GCC countries. The main results of the analysis are formed as recommended actions to be taken by concerned authorities to develop a comprehensive ecological urban system.

3. Theoretical background:

- **Urban ecology:** "*Urban ecology integrates both basic (i.e. fundamental) and applied (i.e. problem oriented), natural and social science research to explore and elucidate the multiple dimensions of urban ecosystems"*[6]. The literature reviews outputted two

different meanings of the ecological system; scientific and urban planning definitions [7]. From scientific point-of-view, Ecological system incudes organisms' resources in and out of the urban settlements. However, from the urban planning point-of-view, the urban ecological system concerns to reduce the impact of urban settlements on the surrounding environment by designing an environmental facility for people [8]. Pickett and others defined the urban ecological system of urban settlement as high population density settlement and its land is mostly covered by built infrastructure [9]. Pickett and others have stated that the less density settlements must be included in the ecological urban system due to the mutual flows and influences between diverse population densities of settlements. Therefore, diverse of large cities, small villages and neighborhoods connected with the same infrastructure could formulate ecological urban system.

• **Urbanism Level:** Countries urbanization levels are increasing through different eras, many of villages developed and changed to cities. This kind of urban development often fragments the large green by buildings, it reduces the size of inhabitant areas and the amount of biodiversity. Thus, the urbanization affects the ecological balance negatively. Eight hundred thousand out of million palm trees have been removed during three decades in Bahrain [10]. 1% of the total area of Korea were green spaces damaged for one decade [11]. On another hand, the desertification affects the greenery land covers; 52% of agricultural land is harshly degraded; 23 hectares of arable are losing per minute due to desertification and drought [12]. Kyushik and other recommended to establish an urban ecological network planning (UENP) as a coordination body to avoid any conflict between ecological planning with the urban development plans. Kyushik assumed that the UENP must consider both the recommendations of scientific research and practical execution of the ecological plans [11]. Proto village in India was a rural settlement serves as a central place of the region, the residents were engaged in urbanism activities. Andreev stated that Proto transformed from village to city settlement due to its central location of the region and urbanism activities of the residents. This kind of changes has negative effect to the ecological system of the village due to reducing the green landcover and increase the urbanism activities, such as industries and construction instead of agriculture [13]. The competitive relationship between villages and cities on using natural resources causes weakness of sustainability cities rather than villages. This is happened because the rural regions are more dependent on natural resources and environment and are more sustainable than the urban regions [14]. Urban regions are classically categorized by lower rates of evapotranspiration and lower albedo than are rural regions. Brian Stone and others referred the reason of such categorization to the big variation of green cover areas in rural and urban regions; including agricultural areas and green roof. Moreover, due to the intensive presence of heat generators and energy consumer machines such as air-conditioning and chiller units, motor vehicles, and other heat sources [15]. Therefore, cities are more considered as higher thermal loads and less ecology than are villages. Figure (2) concludes the literature of urbanism level effect on the ecology of the urban system. It shows history of urban development and land use changes have positive effects on the urbanism level which has negative effects on the ecology of the urban system.

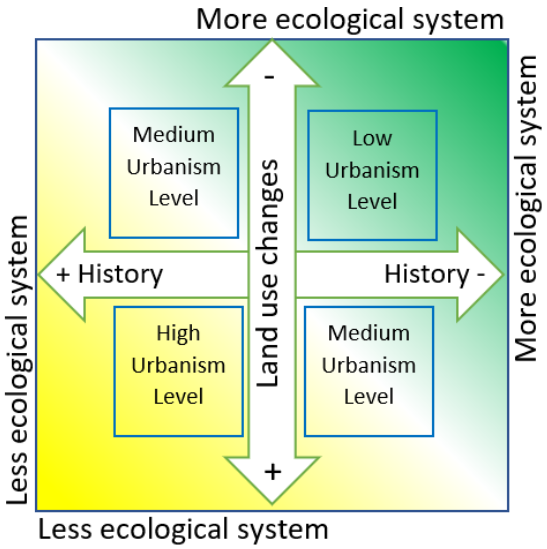


Figure 2: Ecological effects of the urbanism level, history, and land use changes

• **Land Cover:** Global systematic changes of both ecological and social systems are often happened as results of climatic, demographic and technology changes. Such changes are the input data to help bio-physical drivers and land managers of socio-economic projects to take the right decision related to land use plans. Land use and social system feedback, regional and global changes of ecological systems are constructive date for land cover plan [16]. Land cover changes because of the cropland increasing or decreasing changes, tropical deforestation and grassland expansion, while urban land uses growth. Such mutual changes occur because of the global climatic changes and resources shortage. That leads the land managers to look for a compensatory resources production which also motivate the land cover changes as well [17].

Figure (3) concludes the literature of land cover effects on the ecology of the urban system. It illustrates that whenever population increases, the land uses change from greenery to buildings. That change has negative

impact of the greenery land covers and ecology of urban system. Is also shows increasing of the tropical, raining and grass areas has positive impact on the greenery land cover and ecology of urban system

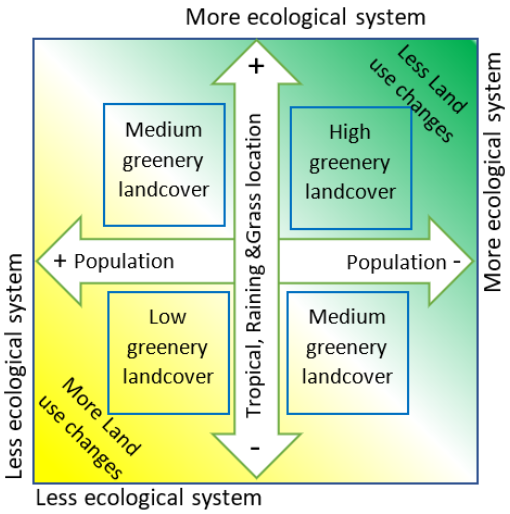


Figure 3: Ecological effects of greenery land cover, land uses changes and geographical characteristics.

• **Urban tissue:** The housing category affects the energy consumption. The amount of energy used in single-family detached houses within sprawling districts is higher than that in the big house within compact districts [18]. Sustainable urbanism is suitable for hot climatic regions that has compact communities and densely inhabited buildings. Such sustainability enhances walk ability and encourage using public transportation rather than private automobiles to reduce per-capita resource use [19]. In the hot and cool climates, the exposure of detached houses into environment without any protection lead to consume energy for cooling and heating respectively. Building sky view factors (height, width and density) affect the long wave radiation loss at the nights and gain at the days. They affect also the solar access to the buildings and open spaces during the day. In addition to their impact on airflow at street level. Grimmond mentioned such factors affect the cooling rates of buildings, daylight, heating of buildings and ventilation of open scarce [20]. The orientation of buildings in grouping pattern to the prevailing wind direction motivate airflow dramatic behaviour. Moreover, configuring the buildings to create oriented central open space exposed to the prevailing wind keeps that space ventilated [21]. Brain Stone and others concluded that there is a need to combine land-use patterns into planning models of any project considering climate change impacts over time [15]. Open urban space has different functions, it various according the income level of the users. For instant, sleeping, vending, recreation is the main function of urban open spaces for low, average and high peoples' incomes respectively [22]. Thus, planners should control extreme temperatures through such strategies of space ventilation, shading, and natural lighting to maintain green spaces within ecological urban system. Figure (4) concludes the literature of urban tissue effects on the ecology of the urban system; where more compact urban forms in more hot climatic zones and less compact urban forms in cool climatic zones is suitable for ecological system.

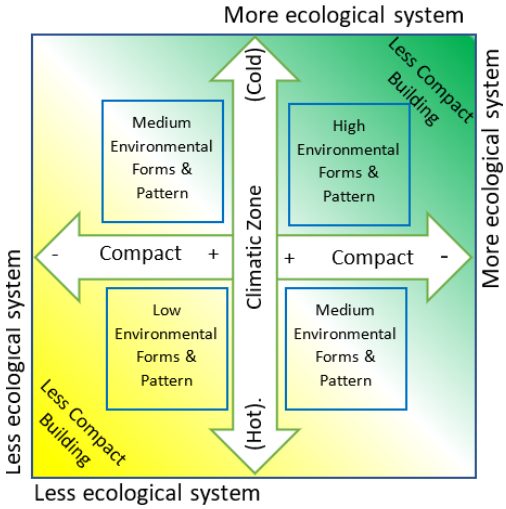


Figure 4: Ecological effects of urban tissue in different climatic zones

• **Urban governance:** Local municipalities are the responsible authorities to transfer the global rhetoric of climatic changes challenges to the local practices; such as carrying out or sponsoring the media to promote ideas of reducing the greenhouse gases. Cities are the most significant arena which address the climatic change for the reasons of: cities contain sites which have the highest consumption of energy and production of waste. Local municipalities of cities have experiences of energy management, planning, transport, environmental measurement which are considered powerful tools of taking the right action for deduction of impacts of the climatic changes [23].

• **Consumed energy:** Different sectors consume energy, such as transportation, manufacturing and building sectors. residential, commercial, industrial and services buildings. The main purposes of consuming energy in the buildings is for atmosphere thermal moderation (Cooling-Heating – Ventilation), lighting and cooking. Peoples consume in the buildings 30 % – 45% of the total consumed energy [24] and they consume in other sectors 30% - 35% each. Energy consumption is increasing due to population growth, the demand energy worldwide has been increased by 2.3% in 2018, 70% of the consumed energy has been produced by fossil fuels but 30% has

been produced as clean energy [25]. These figures of energy consumption indict to relationship of the consumed energy with population and economy. The population growth increases the demanded energy, decreases the fuels' resources and creates an obstacle of developing ecological urban system.

• **Natural resources:** It is defined as the existing resources without human action to produce. Natural resources are existing in form of energy resources or environmental resources. Energy resources are categorized into renewable and non-renewable resources but environmental resources are atmosphere, sunlight, water, animal and land, including minerals, vegetation and crops. There is one type of non-renewable resource, which is fossil fuels (coal, oil and natural gas). There are nine types of renewable resources that used to produce energy, which are solar energy, wind energy, geothermal energy, hydrogen energy, tidal energy, wave energy, hydroelectric energy, biomass energy and nuclear power. Natural resources are the main important things that enhance the country economy, it is known that culture is a factor of conservation of such resources.

4. Discussion

4.1 Potential ecology in GCC countries:

Urbanism Level: The current and projected demographic structure of GCC countries indicates to increasing the urban population ratio as table (1) shows. These facts lead to the demand urban environments rather than rural. Oman has the highest rural population ratio within GCC countries while Qatar has the lowest ratio. This much urbanization is the biggest challenge of developing ecological system in GCC countries. After the oil discovery, many GCC cities have a rapid urban growth, Cities in the GCC countries have been changed from villages to metropolis [26]. In most of GCC cities, highway networks and public transportation systems have been developed; old houses those contain courtyard have been replaced with modern high rise business buildings and towers; large-scale shopping malls replaced the old traditional downtown (Souks) [27]. Urban growth in GCC countries requires Gulf water reclamation to extend the urban land. Moreover, it causes increasing the energy consumption in the buildings and transportation. Such growth of urbanism limits the possibility of ecological urban systems development.

Table (1) The population census on GCC countries

Country	Urban population 2015	Rural population 2015	% urban 2015	Urban population 2025	Rural population 2025	% urban 2025
Bahrain	1,207,101	152,625	88.8%	1,406,447	164,276	89.5%
Oman	3,228,136	929,647	77.6%	3,885,201	885,085	81.4%
Kuwait	3,523,977	59,422	98.3%	4,365,654	66,462	98.5%
Qatar	2,332,785	17,764	99.2%	2,653,239	8,911	99.7%
UAE	8,192,333	1,384,795	85.5%	10,071,980	1,407,120	87.7%
KSA	24,853,959	5,043,782	83.1%	29,085,517	5,121,323	85.0%

Data Sources: *The United Nations, The Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014. Note: both 2015 and 2025 projected populations are based on the medium-fertility variant citied in* (Urban /rural division of countries for the years 2015 and 2025, 2016). [27]

Land cover: According to World Bank identification of the agricultural land area as arable, under permanent crops, and under permanent pastures. Land cover in GCC countries, could be classified as either agricultural land or nonagricultural land. Figure (5) illustrates the percentage of agricultural land in the total land area of each GCC countries though time. It shows that there are no valued extensions in agricultural land cover between 1961 to 2013. The annual expansion of the agriculture land occurred in different yeas with maximum values of: 40%, 2%, 1.43%, 1.4%, 1% and 1% in Saudi Arabia, Arab United Emirates, Qatar, Oman, Kuwait and Bahrain respectively.

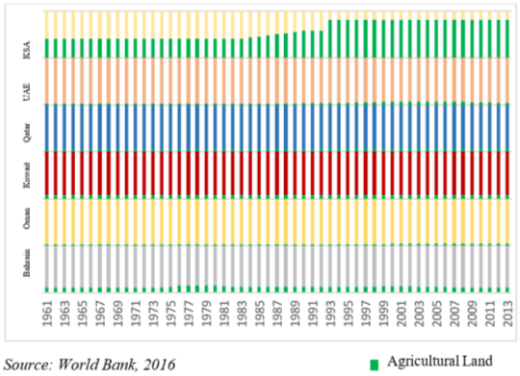


Fig. (5) Land cover in GCC as percentage in land area

Figure (6) shows only Saudi Arabia has excessed the percentage of low- and high-income regions, Europe area, and world average. Insufficient water resources, stop arable land reclamation, and arid climatic are the main reasons of the lack of the green land cover in most GCC countries. These are three challenges of increasing green land cover requires much cost and efforts. Percentages of cultivated land of all GCC countries are less than the average percentage in the world as shown in figure (7). Overall, the green landcover on GCC countries is not very limited comparing with other regions such as Europe and South and Mid Africa as shown in figure (8). Therefore, GCC countries have the opportunity to increase the green land cover as an important element of ecological urban system.

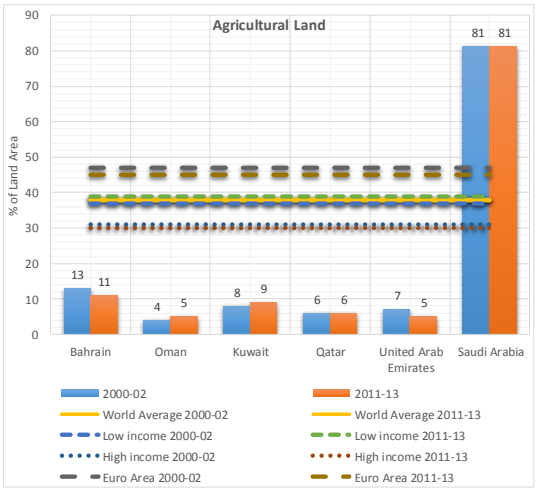


Fig. (6) Percentages of agricultural land on GCC and world (2000 – 2002 and 2011- 2013)

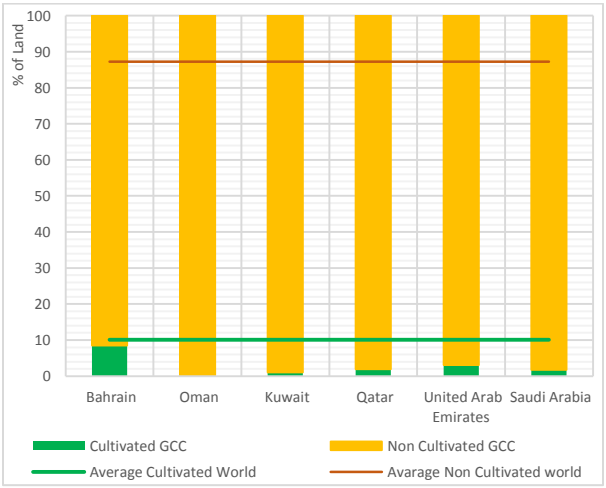
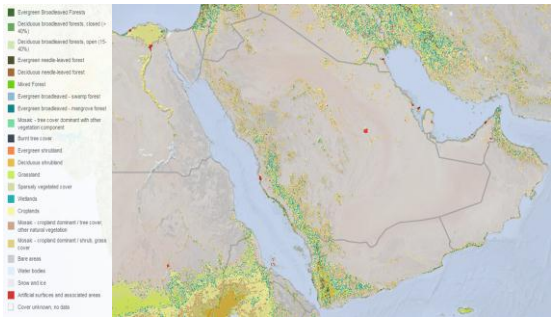


Fig. (7) Percentages of agricultural land on GCC



Source: IRENA Global Atlas, 2015
(http://irena.masdar.ac.ae/?map=2146)

Fig. (8) Land cover map on GCC countries

Urban tissue: Many urban planning researchers concluded their researches that cities in the Arab region have been developed in a variety of heritages and growth patterns. Most of Arab cities were established with a common set of social, geographic, and religious factors. Those factors have impact on developing the urban fabric of the Arab cites [28], [29]and [30]. Moreover, coastal feature is a common in gulf region, thus the development of any city affects the others in all GCC cities [31]. The urban form of GCC cities has been developed through four different phases: in pre-oil phase at 1950s, the urban was developing independently by the native population and the main income source was from marine activities [32], thus, the urban was extending among the seacoasts. At that time, local materials and construction were limited to houses which have a courtyard for natural ventilation and lighting purposes [33]. During the modernization phase at the1960s, the British administration established urban settlements and modern infrastructure in gulf cities, this interfering did not much affect the urban form. But in the oil-price inflation phase at 1970s, massive urbanization has been appeared in the capital cities of the Gulf region in the shape of governmental offices and roads' networks. Since the globalization phase started in 1980s and 1990s, effective planning governance led to developing initial free trade zones and offshore banking and massive construction [34]. At the beginning of the 21st century, a conflict appeared between local and global approaches of urban substantiality.

Urban governance:

Since its independence from the British occupation, every GCC country has its urban planning authority to control the urban growth and development. These planning authorities are developing strategies, plans, regulations and supervising the construction process.

One of the main issues subject to the governance is substantiality, which was absent in building regulations. Since March 2014 green building code started to be implemented in designing any project on Dubai. The Saudi energy code issued on 2018, it concerns with ecological aspects of buildings such as building envelop, HVAC, air quality, water heating and lighting. Building regulations and codes related to sustainability and green buildings are still in the early stage development in some GCC countries such as Bahrain, Kuwait and Oman. A book of shared vision of Sustainable Codes and Standards in the Gulf Region shows that GCC countries cooperation to develop standard codes for sustainable building. It contains cooperation strategies through training, meetings, workshops and conferences to find a common ground of that code. Building Codes of Bahrain, Kuwait and Oman do not contain any mandatory role and regulation regarding to sustainability and ecology; Although they have been signed The United Nations Framework Convention on Climate Change (UNFCCC) to submit action plan to UN within the national communication report. In this report nothing related to adaptation of buildings. i.e., The Bahraini national communication report contains four sectors which are coastal zones, water resources, human health, and biodiversity [35]. In the start of the current century, all GCC countries plan for a mega scale of public transport project. These plans were part of new strategy to reduce the private car driving for daily transport, but only Dubai metro and Abu Dhabi metro have been established in UAE, Mecca metro in KSA [36] and Bahrain Bus in Bahrain.

Since the previous decade, GCC Countries started to develop the building code of sustainability. in 2009, Qatar has the first initiative with GCC countries, it developed (GSAS) Global Sustainability Assessment System. GSAS aims to develop sustainable urban environment through four objectives which are rising the economy, improving the environment, enhancing health and safety and preserving culture identity. The first objective should be achieved by reducing maintenance costs, using green materials, improving the productivity and accelerating buildings' occupancy rates; the second objective should be achieved by conserving biodiversity, creating ecosystems, restoring natural and non-renewable resources, reducing energy consumption, increasing energy efficiency, and ensuring the quality of air, land and water; the third objective should be achieved by enhancing the human comfort and increasing efficacy of infrastructure and public services; the fourth objective should be achieved by conserving and rehabilitating the Arab architecture heritage and encouraging Arab building style. GSAS rating system consists of eight aspects of assessment, including urban community, site, energy, water, materials, indoor environmental quality, culture & economic value, and management and operation [37]. In 2010 United Arab Emirates started to establish ESTIDAMA and ALSAFAT which are Abu Dhabi and Dubai green building codes. The main objective of ESTIDAMA is to preserve and enrich the physical and cultural identity of related United Arab Emirates cities. ESTIDAMA is known internationally as code of sustainable larger scale projects. The integrated development process, natural system, livable community, precious water, resourceful energy, natural materials, and innovation practices are the main aspect of ESTEDAMA assessment criteria [38]. Thus, objectives and assessment aspects of both ESTEDAMA and GSAS contribute for achieving ecological balance of environmental, economic, cultural and social development. Ponzini concluded that due to the globalization trend in GCC countries, the architectural designs of particularly for large-scale projects usually managed by foreign designers and developers in absent of local themes and identity [39].

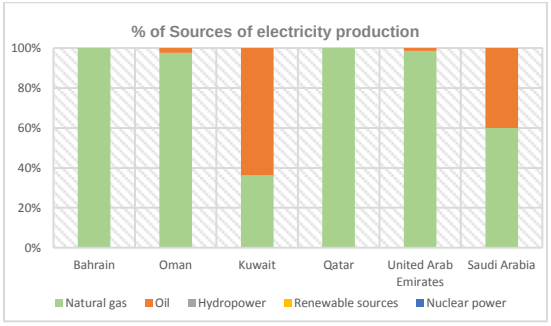


Fig. (9) Percentages of electricity production sources

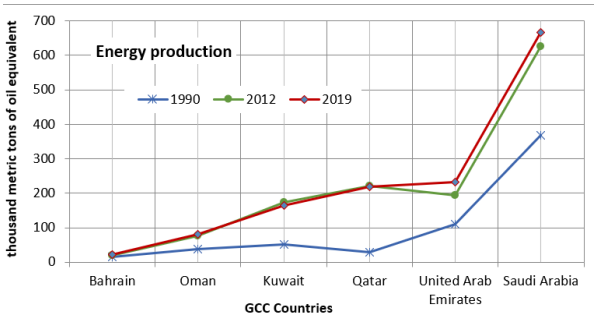


Fig. (10) energy production in GCC countries 1990-2019

Energy resources: Industrial sectors in the six GCC countries are highly oil and gas dependents and fellow with globalization trends [33]. This approach made environmental problems as a result of increasing the carbon dioxide emissions [40]. Kuwait and Saudi Arabia are the most two countries of GCC depend on the oil and gas to produce the energy, while Kuwait is the most oil dependent as shown in figure (9). Before

2012, clean resources such as renewable resources, nuclear power, or hydropower were not used. In 2019, Saudi Araba burned 399 thousand metric tons of oil and 266 thousand metric tons of natural gas to produce 378,153 GWh as shown in figure (9), (10) and (11). Saudi Arabia is the largest consumer of oil globally, it uses more than three million barrels of oil per day for power production [41]. However, rate of energy production in Saudi Arabia is the highest and Bahrain rate is lowest, energy use per capita in Saudi Arabia is the lowest as shown in Figure (12).

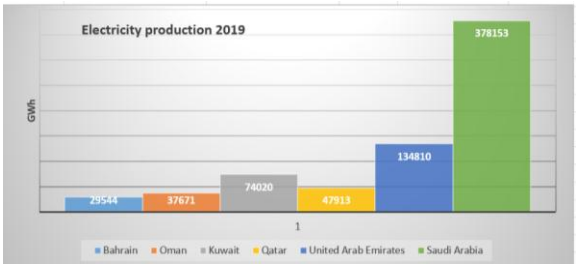


Fig. (11) amounts of electricity production in GCC 2019

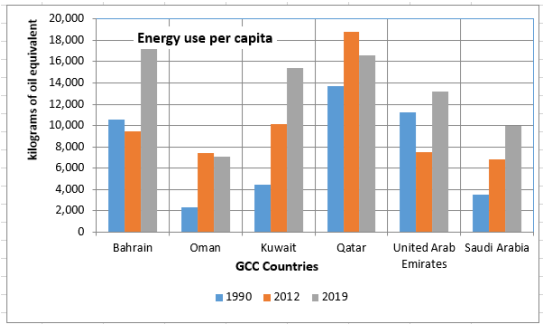


Fig. (12) energy use per capita in GCC

GCC region locates in the Global Sunbelt which exposes to the highest solar irradiances in the world. Therefore, GCC countries are well endowed with renewable energy that can be produced from profusion of solar irradiation among the entire region of GCC. They could produce annually 1778 kWh/m^2: 2655 kWh/m^2 [42] & [41]. Large scale projects have been announced for utilizing the solar energy in the countries located in the Sunbelt to obtain photovoltaic potential energy [43]. Kuwait, Oman and Saudi Arabia locations have wind resources with relatively high speed (between 5 and 7.5 m/s). Wind resource could be utilized in 56% of surface area of GCC region; Using 1% of such area could generate 60 GW [42].

GCC countries changed their policy of using energy, they have plan to produce renewable energy for coming 30 years. Bahrain announced that 25 MW of waste-to energy capacity in 2030; Qatar produces 100 MW of solar photovoltaic capacity starting from 2014; Kuwait planned 70 MW of renewable capacity of solar photovoltaic; Saudi Arabia will produce 54 GW of renewable energy using solar photovoltaic by 2032; Oman planned to produce 100-200 MW from solar photovoltaic; and The United Arab Emirates' plan is by the end of 2030, Dubai will produce 5% of final energy from renewables and by 2020 Abu Dhabi will have 7% of capacity from renewables [44]. All GCC countries started to implement their plan, all together produced about 770 GWh electricity in 2016 and 1981 GWh in 2019 [45]. This big inclement indicates to the trend of changing the main source of energy to be renewable energy as shown in figure (13)

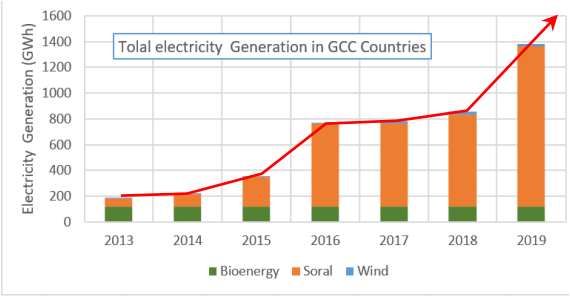
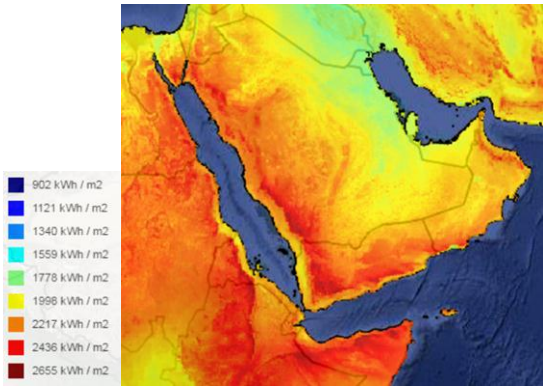


Fig. (13) The total electricity generation from renewable energy in GCC Countries

Natural resources:

- **Renewable energy resources:**

According to many studies and researches about the potential energy, solar and wind energy are the main and feasible renewable resources in GCC countries [46], [47], [48], [49], (Alnaser & Flanagan, 2007), [50], [51], [52], [53], [54], [55], and [56]. Fig. (14) shows that from solar radiation and wind, KSA and Oman could generate annually about 1998:2655 KWh/m2 at large areas their lands, UAE could generate annually about 1998 KWh/m2 of most of its lands, while



Source: (IRENA, Global Atlas, 2005) [57]

The yearly irradiation values are computed only for the pixels for which 12 monthly irradiation values are available

Fig. (14) GCC yearly irradiation by wind and solar resources

Bahrain, Kuwait and Qatar could generate annually about 1559 : 1998 KWh/m2 of all their lands. Table (2) shows that the GCC countries have more than 93% potential solar and wind energy over current needs.

Table (2) the potential renewable energy in GCC countries

Name of GCC Country	Consumption*	Potential Solar**	Potential Wind**	Total	% of consumption
	(Twh) /Year				
KSA	274.5	124560	145104.1	269664.1	0.10
UAE	111.7	2087	5434.0	7521.0	1.49
Oman	31.3	7600	38764.9	46364.9	0.07
Kuwait	60.5	1525	1225.0	2750.0	2.20
Qatar	36.1	792	2027.6	2819.6	1.28
Bahrain	12.6	33	156.3	189.3	6.66

* (Wogan, Pradhan, & Albardi, 2017) [59]

** (Bachelleric, 2012) [60]

Water:

There are five types of water resources could be used in GCC countries; precipitation which comes direct from rainfall, surface water which is collected in lakes; groundwater which is obtained from aquifers and springs; desalinated water which is collected from the seas, and treated wastewater which is collected from the sewage [58]. Table (3) indicates to the big variation between precipitation and surface water amounts. But usually rainfall water not used properly in GCC countries due to rare of rainfall and random frequency of falling.

- **Additional energy resources**

Biomass and geothermal power technologies may hold additional potential which are under exploration process in GCC countries [42]. Waste-to-energy is very important renewable energy option. Fig (15) shows amounts of solid waste those are generated annum in GCC countries. That indicates to the huge amount of the potential energy could be generated by converting waste-to- energy.

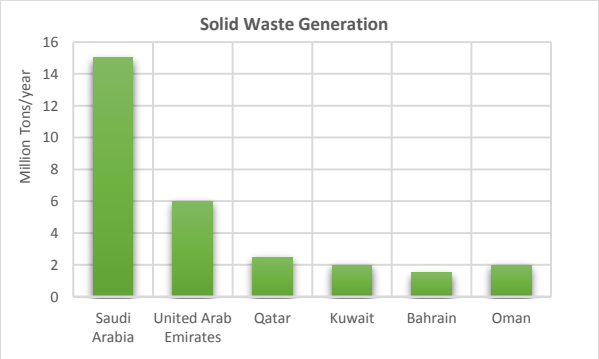


Fig. (15) solid waste are generated annum in GCC countries

Table (3) The annual amount of available water in GCC countries

Water resources	Bahrain	Qatar	Oman	Kuwait	KSA	UAE	GCC	Per capita /day
Precipitation	48.3	NA	29,495.40	1,585.80	192,795.60	NA	225,743.90	11.582
Surface water	0	0	102	0	175	25	277	0.014
Ground water	155.1	NA	1,083.70	85.2	21,595.00	NA	26,705.20	1.370
Desalinated water	241.9	560	279.6	712.4	1,947.00	2,004.90	5,745.70	0.295
Treated wastewater	69.9	203.3	66.9	246.7	1,604.30	746.4	2,924.10	0.150
Total	2,531.2	2,779.3	33,043.6	4,646.1	220,132.9	4,792.3	263,411.9	13.515

Data in million cubic meters.
Data source: (Water Statistics Report in GCC Countries, 2018) [58]

- **Marine and coastal habitats:**

The Gulf region contains an unique marine environment, but the rapid tremendous changes of the coastlines accrued in many of coastal cities threaten the marine life sustainability [61]. The Arabian Gulf accommodates 6% of seagrass habitats in the whole world. It serves as the main food source for the largest population of green turtles and dugongs, it also

contributes on fisheries productivity [62]. There are 2,358,013 Km2 are protected in GCC countries which are 5% of the terrestrial areas and 1.52% of the marine areas. UAE and Kuwait have the highest coverage of land protection, while Oman is the lowest coverage. UAE is the only the country that has high coverage of marine protection. In another hand, Saudi Arabia country has the largest protected land and marine areas, it contains 82.25% of the total protected land and marine areas of GCC countries. Bahrain has the smallest protected land and marine areas; it contains 0.03 % of the total protected land and marine areas of GCC countries. That fact is normal due to the large variation between their total areas.

Table (4) terrestrial and marine areas in GCC countries

Country	Number of Protected areas	Area terrestrial			Area marine			Total Protected Areas (Km2)	%
		Land Area Protected (KM2)	Total Land Area (km2)	Coverage (%)	Marine Area Protected (KM2)	Total Marine Area (KM2)	Coverage (%)		
Bahrain	8	45	687	6.55	95	7,633	1.24	782	0.03
Saudi Arabia	70	92,064	1,934,058	4.76	5,495	220,338	2.49	1939553	82.25
Kuwait	39	2,979	17,418	17.10	162	11,896	1.36	17580	0.75
Qatar	5	1,513	11,436	13.23	538	31,988	1.68	11974	0.51
Oman	16	7,985	310,373	2.57	664	538,980	0.12	311037	13.19
UAE	51	12,734	70,921	17.96	6,166	54,711	11.27	77087	3.27
Total GCC Country	189	117320	2344893	5.00	13,120	865,546	1.52	2358013	100.00

Source: (UN-EPWCMC, 2019) [63]

There are 16,271 km shorelines in GCC countries are distributed on each according to the percentage shown in figure (16). These shorelines are generally not well developed due to the arid weather, although thermal comfort in outdoor areas is recorded during at October, November and December, in which the average temperature is less than 24 and humidity is less than 40%.

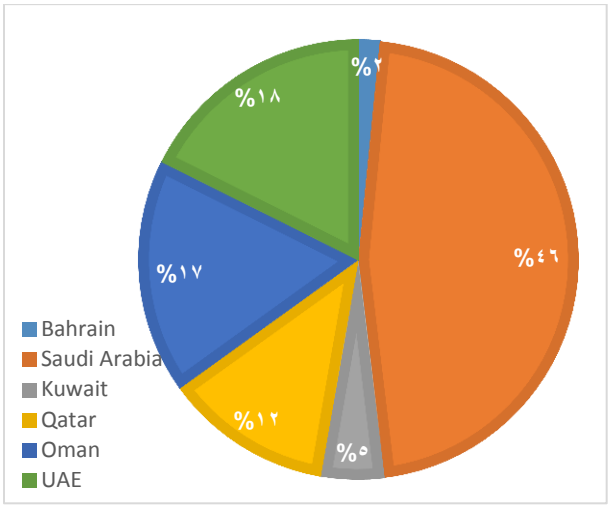


Fig. (16) shorelines percentage among GCC countries

4.2 Obstacles of ecology in GCC countries:

Air pollution:

In the last decade of the twentieth century, all GCC countries recorded air pollution higher than the average world but lower that Europe. In most of the world countries, air pollution rate increased more during the first two decades of twenty first century while decreased on Europe, but the increasing rate in GCC countries was much higher than in the world and even in the low-income countries. The main reasons of this facts illustrated in figure (17) are absent of mitigation strategies, high CO2 emissions due to high rates of the fuel consumption, increasing numbers of cars, nonoptimal use of vehicles, absence of public transportation in some areas, and unavailability of water.

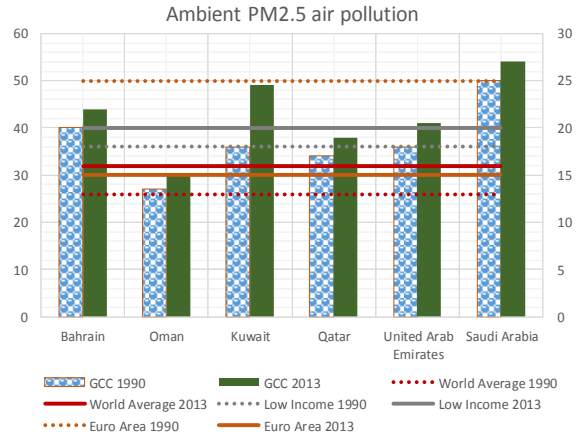
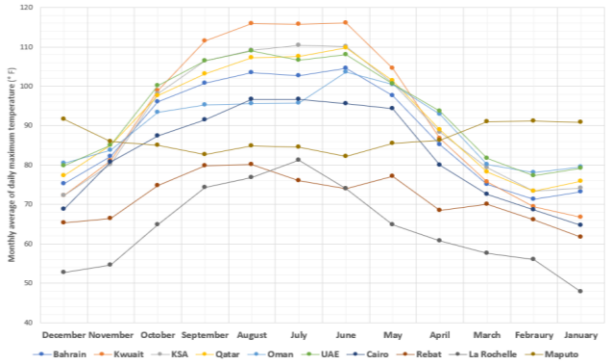


Fig. (17) Air pollution rates in GCC, Europe and world

Harsh weather:

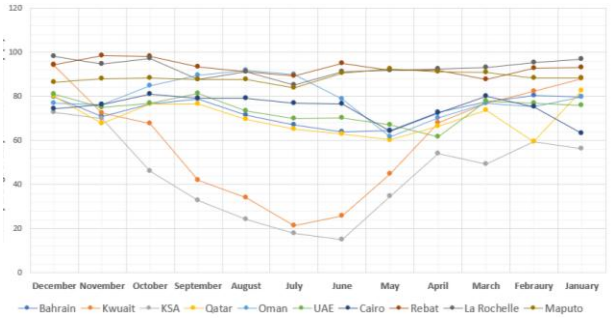
GCC countries suffer from an arid weather during most of the year sessions, figures (18) and (19) show that temperature is usually high comparing with other cities

have similar and higher humidity. This harsh weather affects the planets, terrestrial and marine organisms. High temperature and humidity in GCC countries drive the peoples for more energy consumption to creating human thermal comfort inside buildings.



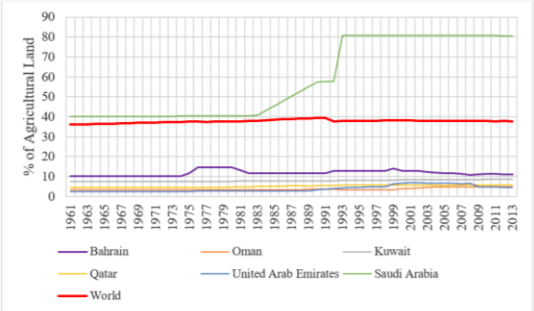
Data source: (Weather Underground, 2020) [64]

Fig. (18) Monthly average of daily maximum temperature in GCC and others' cities



Data source: (Weather Underground, 2020) [63]

Fig. (19) Monthly average of daily maximum humidity in GCC and others' cities



Data source: (World Development Indicators, 2016) [66]

Fig. (20) Percentage of agricultural land in GCC Countries

Water resources:

(FAO) Food and Agriculture Organization of United Nation classified most of GCC Countries as water poor countries, UAE, Bahrain, Qatar, Kuwait produce natural water of amounts 0.15, 0.12, 0.05, 0.02 Km3 / year respectively, while Brazil produce 31795 m3/ year [65]. This variation is a result of rivers absent, moreover soil salt of gulf areas effect on quality the underground water. Fig (20) shows the low percentage of agricultural land in GCC except KSA in comparing with other world countries, the main reason is the lack of natural water. The figure shows that although KSA has 40% of its land used for agriculture which is higher than other world countries, but also it developed more land in 1991 and retched 80%. Nevertheless, the remaining GCC countries do not have any development since 1961 although they have not used more than 10 % of the land in agriculture.

5. Analysis and results:

The author used SWOT analysis method to analyze the factors of achieving urban ecological systems in GCC countries. The analysis includes identifying the strengths of the GCC countries which are already achieved toward ecological urban system; weaknesses of the current systems which could be enhanced; possible opportunities those need to be utilized optimally; and possible threats which should be controlled to avoid failing developments of ecological urban system.

Despite the negative impact of urbanization on the ecological system, urbanization has become a necessary requirement for most people. They enjoy modern luxury means away from the hard work of cultivating the land. Therefore, cities and villages must be developed to bring them without prejudice to the natural environment of plants, aquatic and wildlife, water, etc.

Since the greenery of the land cover is one of the most important factors for the success of creating an urban ecosystem. And with refereeing to the possibility of increasing greenery in the land cover in the GCC countries - which was been limited for a long time- It is necessary to increase the greenery areas on the land cover through a long-term plan. Such plan must include defining the arable areas and find methods to improve agricultural productivity in the harsh climate of the GCC region. It also must include the methods of horizontal expansion by preparing and reclaiming non-cultivated lands. In addition to working on utilizing the roofs of buildings to launch the green roof project. This plan would be handled by urban planning authorities. They must develop regulations of land uses to conserve the current greenery land cover areas and increate it as well as maximize the implementation of the green buildings' codes.

The flexibility of urban formation in the GCC countries is a great advantage in controlling urban growth and adjusting its form and pattern. Where building laws and regulations must be enacted so that building configurations are environment-friendly in terms of building uses; building materials; thermal insulation; self-shading, building envelope materials and optimal exploitation of wind, energy, light, and water.

STRENGTHS	WEAKNESSES
•Increasing of agricultural land in Saudi Arabia to 81% which has excessed the agricultural land percentage in low- and high-income regions which are 38 & and 31% respectively. •Urban planning authority has been established on all GGC countries to control the urban growth and development through developing strategies. •Green building code started to be implemented in some countries practically UAE and Qatar. •Transform to public transportation to reduce the energy consumption by the private. (Dubai metro and Abu Dhabi metro have been established in UAE, Mecca metro in KSA and Bahrain Bus in Bahrain). •GCC countries changed their policy of using energy and plan to produce renewable energy for coming 30 years. •There are 2358013 Km2 are protected in GCC countries which are 5% of the terrestrial areas and 1.52% of the marine areas. •There are 16271 km shorelines in GCC countries. •KSA had 40% of its land used for agriculture, which is higher than other world countries, but also it developed more land in 1991 and retched 81%.	•Extensions of agricultural land cover in most GCC countries except KSA is very limited, especially between 1961 to 2013. •GCC countries are highly depend on oil and gas for industrial sectors aiming to transform into globalization. In 2019, they produced 702111 GWh using oil and natural gas while produced only 1981GWh using renewable recourses. •The big difference between precipitation and surface water amounts which are annually 225,743.90 and 277 Cubic meters respectively indicates to improperly use of rainfall water because of, rare of rainfall, random of falling causes not exiting lakes or rivers. •High air pollution records in all GCC countries, Oman recorded 30 micrograms per cubic meter, while KSA recorded 54 micrograms per cubic meter, which are more than the average world records. •Arid weather and hot air in GCC countries most of the year sessions affects the life of peoples, animals and plants; practically during summer session the air temperature reached 46 ^{o}C •Rare of water resources in GCC countries causes absent of agricultural development.

OPPORTUNITES	THREATS
•Existing of coastal feature in which there are 16,271 km shorelines in GCC countries, that encourages the coastal zones. •Initiatives of some GCC countries for developing building regulations and codes related to sustainability and green buildings. •Cooperation of GCC countries to develop standard codes for sustainable building through training, meetings, workshops and conferences. •Existing of plan for mega scale of public transport projects, these plans were part of new strategy to reduce the private car driving for daily transport. •Qatar has the first initiative within GCC countries in which Global Sustainability Assessment System (GSAS) has been developed in 2009, other GCC countries might join Qatar in its initiative. •Establishing ESTIDAMA and ALSAFAT which are Abu Dhabi and Dubai green building codes, those could be good references for the other cities. •GCC locations in Sunbelt causes profusion of solar irradiation among the entire region of GCC, that is a great chance for producing effective and big amount of renewable energy which is more than 93% of current needs. •Future large-scale projects that have been announced for utilizing the solar energy in GCC countries. •Existing of relatively high-speed winds (between 5 and 7.5 m/s) on more 56% of surface area of GCC region that are located in Kuwait, Oman and Saudi Arabia. This wind resource could be utilized in might be a good source of renewable energy. •The feasibility of producing solar and wind energy in GCC countries. •Huge amount of potential wind and soral that could produce 329,309 TWh in all GCC countries which are 9 times of the current consumption of electricity. •Huge amount of waste of about 29 million tone per year is a great potential energy resource. •Gulf region contains a unique marine environment. •Existing of thermal human comfort season at outdoor areas overall GCC countries might reduce energy consumption and prevent the live things.	•Urbanization, which is bead on western building materials with glassing and metal without considering the environmental context is the biggest challenge of developing ecological system in GCC. •Increasing of gulf water reclamation in some GCC cites threaten the marine life and shorelines •Insufficient water resources threaten green and agriculture. •Occurred conflict between local and global approaches of urban substantiality. •Rapid undergone tremendous change of the coastlines threatens the marine life •The increasing rate of air pollution in GCC countries threaten ecology environment. •Increasing of energy consumption that demanded to create human thermal comfort inside buildings during summer season.

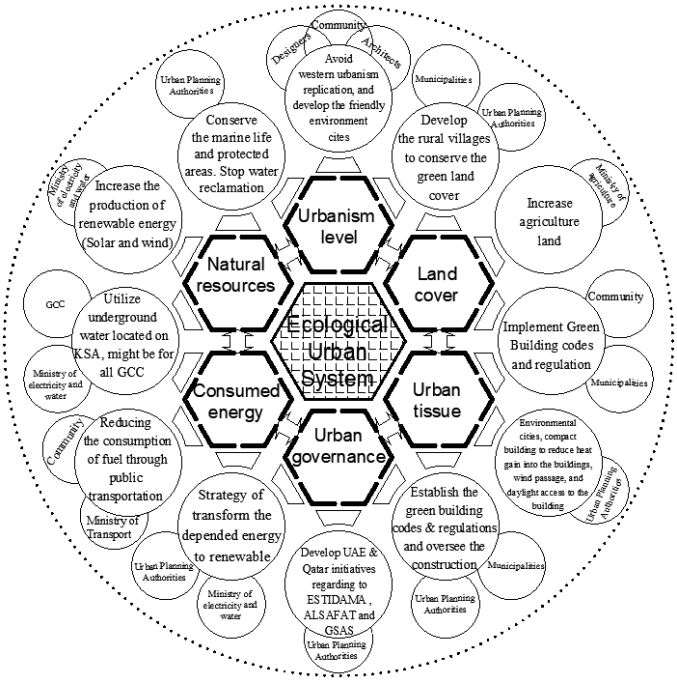
6. Conclusions and recommendations:

Based on the above studies of this research, the author concludes the followings:

- GCC countries are not far beyond the ecological urban systems. This is a fact extracted from initiatives of some countries towards ecological achievements, huge potentials of renewable and additional energy, costal features of Gulf cities including marine life and the cooperation of GCC countries to support each other and challenge the obstacles.
- Urban developers in GCC countries are required to collaborate with each other and take some furthered and managed actions for achieving a comprehensive ecological urban system.

The author summarizes such recommended action as shown in figure (21), and attached matrix as listed below:

- An authority must be established on each country to manage and coordinate the ecological urban system with other partners in the country and a union must be established under GCC to coordinate the ecology issues between the authorities. For the governance aspect, urban planning authority in each country should start developing UAE and Qatar initiatives of establishment the green building codes and regulations. Such cods and regulations should be combatable with gulf region. It would lead to create and develop environmental cities with compact building to reduce heat gain into the building, wind passage, and daylighting access to the building.
- In the collaboration with the urban planning authority, the municipalities should oversee the construction process and supervise the community to ensure implementation of the green building codes and regulations.
- The ministry of agriculture should do more efforts to increase the agriculture land, while municipalities and urban planning authorities should support in conserving the existing green land cover. They must develop and implement regulations to prevent scraping the agriculture lands for building construction.
- Urban planners and architects are partners with the community to avoid replica of eastern urbanization and to develop eco-friendly cities through considering environmental factors of the Gulf region.
- Urban planning authorities should stop sea water reclamation through developing planning law and regulation to conserve the marine life. In addition to implement the international policies of protected areas to discover, register and develop more natural protected areas.
- Ministry of electricity and water should produce renewable energy according to ascending plan from reducing fuel consumption until full transforming into renewable energy for all residential and industrial sectors. As beyond that the GCC countries can export electricity to northern neighbor regions.
- One of the main sectors should contribute on decreasing the fuel consumption is the transportation. Therefore, Ministry of transportation should enhance the public transportation systems; cover all inhabitant areas and facilitate the peoples' mobility.
- GCC countries must take the strategic actions to facilitate the tasks of the proposed union, such as support agreement for utilizing the underground water of KSA.



Objectives		Action	Responsible	Designers	Architects	Community	Municipalities	Urban Planning Authorities	Ministry of electricity and Water	Ministry of Transport	Ministry of Agriculture	GCC
Sustain green land cover	Maintain the balance of urbanism level	Develop the rural villages to conserve the green land cover.					✓	✓				
		Avoid western urbanism replication and develop friendly environment cities.		✓	✓	✓						
Sustain the natural resources		Conserve the marine life and protected areas and stop water reclamation.						✓				
		Increase the production of renewable energy.							✓			
	Control energy consumption	Utilize underground water located in KSA							✓			✓
		Reduce the consumption of fuel through using public transportation.				✓				✓		
Manage urban governess		Develop strategy of transform the depended energy to renewable.						✓	✓			
		Develop UAE and Qatar initiatives of ESTEDAMA, ALSAFAT and GSAS						✓				
	Manage and maintain urban tissue	Establish green building codes & regulations and overseen constructions.					✓	✓				
		Use environmental planning solutions.						✓				
Sustain green land cover		Implement and activate and building codes & regulations				✓	✓					
		Increase agriculture land									✓	
		Develop the rural villages to conserve the green land cover.					✓	✓				

Figure (21): Diagram of actions toward ecological urban system in GCC countries

7. References:

[1] UNESCO Statement . (2014, May 27-19). Retrieved from ECOSOC Integration Segment on Sustainable: http://www.un.org/en/ecosoc/integration/pdf/unesco.pdf

[2] Mukherjee, J. (2018). Indian Urban Trajectories: Addressing sustainability across Micro-political settings. In J. Mukherjee, Sustainable Urbanization in India (pp. 1-22). Kharagpur: Springer.

[3] Walters, D. (2017). Urban Design for Architects: Space, Place, And Urban Infrastructure. Pewaukee: PDH Academy.

[4] Soliman, A. M., & Alkhalefa, A. M. (2018). CHARACTERISTICS OF SOCIO-ALIVE BUILDING: THE CASE OF BAHRAIN CITY CENTER. Journal of Architecture and Urbanism, 42(2), 155-168. doi:https://doi.org/10.3846/jau.2018.6142

[5] IRENA. (2016). renewable energy in the gulf: facts and figures. International Renewable Energy Agency.

[6] McDonnell, J. M. (2011, PP 9). The History of Urban Ecology, An Ecologist's Perspective. In N. Jari, H. B. Jürgen, E. Thomas, G. Glenn, J. Philip, & E. M. Nancy, Urban Ecology, Patterns, Processes, and Applications (pp. 5-13). Oxford: Oxford University Press.

[7] Breuste, J., Feldmann, H., & Uhlmann, O. (1998). https://link.springer.com/book/10.1007/978-3-642-88583-9. Berlin: Springer. doi:https://doi.org/10.1007/978-3-642-88583-9

[8] Deelstra, T. (1998). Towards Ecological Sustainable Cities: Strategies, Models and Tools. In J. Breuste, H. Feldmann, & O. Uhlmann, Urban Ecology (pp. 17-22). Berlin, Heidelberg: Springer. doi:https://doi.org/10.1007/978-3-642-88583-9_2

[9] Pickett, S., Cadenasso, M., Grove, J., Nilon, C., Pouyat, R., Zipperer, W., & Costanza, R. (2001). Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas. Annual Review of Ecology and Systematics, 32, 127-157. doi:https://doi.org/10.1146/annurev.ecolsys.32.081501.114012

[10] Sebaa, A. (2014, July 6). Will the palm trees disappear in Bahrain? Al Wassat.

[11] Kyushik Oh , Dongwoo Lee & Changsug Park. (2011). Urban Ecological Network Planning for Sustainable Landscape Management. Journal of Urban Technology, 18(4), 39-59. doi: 10.1080/10630732.2011.648433

[12] UNCCD. (2015, June). World Day to Combat Desertification. Retrieved April 8, 2016, from Welcome to the United Nations. It's your world.: http://www.unccd.int/Lists/SiteDocumentLibrary/WDCD/DLDD%20Facts.pdf

[13] Andreev, Y. (1989, July). Urbanization as a Phenomenon of Social History. Oxford Journal of Archaeology, 167 - 177.

[14] Lishan Xiao Zhichao He, Ying Wang & Qinghai Guo. (2016). Understanding urban–rural linkages from an ecological perspective. International Journal of Sustainable Development & World Ecology, 1-7.

[15] Brian Stone, Jeremy J. Hess, and Howard Frumkin. (2010). Urban Form and Extreme Heat Events: Are Sprawling Cities More Vulnerable to Climate Change Than Compact Cities? Environmental Health Perspectives, 118(10), 1425-1428.

[16] Alcamo, J., Busch, G., Chhabra, A., & others, a. (2006). Land-Use and Land Cover Change - local process and global impacts. (H. G. Eric F. Lambin, Ed.) New York: Springer.

[17] Lambin, E. F., Geist, H. J., & Lepers, a. E. (2003). Dynamics of Land-Use and Land-cover Change in Tropical Regions. Annual Review of Environment and Resources, 28, 205-241.

[18] Reid Ewing, and Fang Rong. (2010). The impact of urban form on U.S. residential energy use. Housing Policy Debate, 1-30.

[19] Furlan, R. (2017). Urban Regeneration of GCC Cities: Preserving the Urban Fabric's Cultural Heritage and Social Complexity. Journal of Historical Archaeology & Anthropological Sciences, 1(1), 1-6. doi:10.15406/jhaas.2017.01.00004

[20] Grimmond, S. (2007). Urbanization and global environmental change: local effects of urban warming. GJ The Geographical Journal, 173(1), 83-88.

[21] Asfour, O. S. (2010). Prediction of wind environment in different grouping patterns of housing blocks. Energy and Buildings, 2061–2069.

[22] Paraschiv, M. (2013). Urban Space Patterns and Homelessness in Bucharest, Romania. REAL CORP, (pp. 1405-1409). Rome.

[23] Bulkeley, H., & Betsill, M. M. (2005). Cities abd Climatic Change - urban and sustainability and global environmental governance. London and New York: Routledge.

[24] Mehreen, S. G., & Sandhya, P. (2015). Understanding the energy consumption and occupancy of a multi-purpose academic building. Energy and Buildings, 87, 155-165. doi:https://doi.org/10.1016/j.enbuild.2014.11.027

[25] (2018). Key World Energy Statistics 2018. IEA.

[26] Bennison, K. A., & Gascoigne, L. A. (2009). Cities in the Pre-Modern Islamic World: The Urban Impact of Religion, State and Society. Journal of Islamic Studies, 19(3), 405-407.

[27] WIEDMANN, F., SALAMA, A. M., & THIERSTEIN, A. (2012). URBAN EVOLUTION OF THE CITY OF DOHA: AN INVESTIGATION INTO THE IMPACT OF ECONOMIC TRANSFORMATIONS ON URBAN STRUCTURES. METU JFA, 29(2), 35-61. doi:10.4305/METU.JFA.2012.2.2

[28] Lapidus, M. I. (1969). Middle Eastern Cities. Berkeley: University of California Press.

[29] Saqqaf, Y. A. (1987). The Middle East City. :. New York: Paragon House.

[30] Kiet, A. (2011). Arab Culture and Urban Form. Focus, 8(1). doi:10.15368/focus.2011v8n1.4

[31] Koolhaas, R., & Reisz, T. (2010). Al Manakh Gulf Continued. Amsterdam: Stichting Archis.

[32] Al-Maimani, A., Salama, A. M., & Fodil, F. (2014). Exploring socio-spatial aspects of traditional souqs: the case of souq Mutrah, Oman. ArchNet-IJAR: International Journal of Architectural Research, 8(1), 50-65. doi:10.26687/archnet-ijar.v8i1.356

[33] AL-Mohannadi, A. S., & Furlan, R. (2018). The Practice of City Planning and Design in The Gulf Region: The Case of Abu Dhabi, Doha and Manama. Archnet-JAR: International Journal of Architecture Research, 12(2), 126-145. doi:10.26687/archnet-ijar.v12i2.1460

[34] Khalaf, S. (2006). The evolution of the Gulf city type, oil, and globalization. In N. S. Fox, & M. Al Mutawa, Globalization and the Gulf (pp. 244 - 265). London: Routledge.

[35] (2012). Bahrain's Second National Communication . Manama: Public Commission for the Protection of Marine Resources, Environment and Wildlife.

[36] (2009). Global Mass Transit Report. Global Mass Transit. Retrieved from https://www.globalmasstransit.net/archive.php?id=427

[37] Alhorr, Y. M. (2017). GSAS TECHNICAL GUIDE . Doha: Gulf Organisation for Research & Development.

[38] (2010). Pearl Building Rating System: Design & Construction. Abu Dhabi: Abu Dhabi Urban Planning Council.

[39] Ponzini, D. (2011). Large scale development projects and star architecture in the absence of democratic politics: The case of Abu Dhabi, UAE. Cities, 28(3), 251-259. doi:dx.doi.org/10.1016/j.cities.2011.02.002

[40] UN-Habitat. (2012). UN-Habitat Annual Report. UN-Habitat. Retrieved from http://unhabitat.org/un-habitat-annual-report-2012/

[41] Stratfor. (2016, Novmber 21). A Bright Future for Solar Power in the Middle East. Retrieved from Stratfor : https://www.stratfor.com/analysis/bright-future-solar-power-middle-east

[42] Rabia Ferroukhi, Arslan Khalid, Diala Hawila, Divyam Nagpal. (2016). Renewable Energy Market Analysis: The GCC Region. Abu Dhabi: (IRENA) International Renewable Energy Agency.

[43] A.T. Kearney, Jochen Hauff, Marnik Verdonck, Harold Derveaux, Laurent Dumarest, Jose Alberich and Jean-Charles Malherbe. (2010). Unlocking The Sunbelt Potential of Photovoltaics (2nd ed.). Brussels - Belgium: European Photovoltaic Industry Association (EPIA).

[44] IRENA. (2012). renewable energy in the gulf: facts and figures. International Renewable Energy Agency.

[45]. (2019). Statistices . International Renewable Energy Authority.

[46] Al-Qahtani, H. (1996). Feasibility of utilizing solar energy to power reverse osmosis domestic unit to desalinate water in the state of Bahrain. Renewable Energy, 8(1), 500-504. doi:10.1016/0960-1481(96)88907-5

[47] Karaghouli, A. A., & Alnaser, W. E. (2001). Experimental study on thermosyphon solar water heater in Bahrain. Renewable Energy, 24(3-4), 389-396. doi:10.1016/S0960-1481(01)00020-9

[48] Franz , T. (2005). Concentrating Solar Power for the Mediterranean Region. Germany: German Aerospace Center (DLR).

[49] Alnaser, N. W., & Flanagan, R. (2007). he need of sustainable buildings construction in the Kingdom of Bahrain. Building and Environment, 42(1), 495-506. doi:10.1016/j.buildenv.2005.08.032

[50] Frenken, K. (Ed.). (2009). Irrigation in the Middle East region in figures: AQUASTAT Survey – 2008. Roma: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

[51] Gastli, A., & Charabib, Y. (2010). Solar electricity prospects in Oman using GIS-based solar radiation maps. Renewable and Sustainable Energy Reviews, 14(2), 790-797. doi:10.1016/j.rser.2009.08.018

[52] Gastli, A., & Charabi, Y. (2010). GIS assessment of large CSP plant in Duqum, Oman. Renewable and Sustainable Energy Reviews, 14(2), 835-841. doi:10.1016/j.rser.2009.08.019

[53] Doukas, H., Patlitzianas, K. D., Kagiannas, A. G., & Psarras, J. (2006). Renewable energy sources and rationale use of energy development in the countries of GCC: Myth or reality? Renewable Energy, 31, 755–770. doi:10.1016/j.renene.2005.05.010

[54] Marafia, A. H. (2001). Feasibility study of photovoltaic technology in Qatar. Renewable Energy, 24(3-4), 565-567. doi:10.1016/S0960-1481(01)00042-8

[55] Al-Ammar, E. A., & Al-Aotabi, A. (2010). Feasibility study of establishing a PV power plant to generate electricity in Saudi Arabia from technical, geographical and economical viewpoints. International Conference on Renewable Energies and Power Quality. 1, pp. 941-946. Granada : European Association for the Development of Renewable Energies, Envi-ronment and Power Quality. doi:10.24084/repqj08.530

[56] El Chaar, L., & Lamont, L. A. (2010). Global solar radiation: Multiple on-site assessments in Abu Dhabi, UAE. Renewable Energy, 35(7), 1596-1601. doi:10.1016/j.renene.2009.10.007

[57] IRENA. (2005). Global Atlas. IRENA. Retrieved from http://irena.masdar.ac.ae/?map=2146

[58] (2018). Water Statistics Report in GCC Countries. Muscat: GCC-STAT.

[59] Wogan, D., Pradhan, S., & Albardi, S. (2017). GCC Energy System Overview – 2017. Riyadh : KAPSARC.

[60] Bachelleric, I. J. (2012). Renewable Energy in GCC Countries: Resources, Potential, and Prospects. Gulf Research Center.

[61] Van Lavieren H., J., Burt, D., Feary, G., Cavalcante, E., Marquis, L., Benedetti, C., & Trick, B. K. (2011). Managing the growing impacts of development on fragile coastal and Marine ecosystems: lessons from the gulf. Hamilton: UNU-INWEH.

[62] Paul, L. E., & Dawood, A. S. (2012). Seagrass habitats in the Arabian Gulf: distribuation, tolerance thresholds and threats. Ecosystem Health and Managmnet(15), 73-83.

[63] UN-EPWCMC. (2019). Data of Terrestrial and Marine areas. Untited Nations - Environment Program World Conservation Monitoring Centre.

[64] Weather Underground. (2020, December 07). Retrieved from Weather Underground: https://www.wunderground.com/history

[65] FAO. (2019, December 07). WORLD WATER RESOURCES BY COUNTRY. Retrieved from http://www.fao.org/3/y4473e/y4473e08.htm

[66] (2016). World Development Indicators. USA: World Bank.

Acknowledgment:
The author acknowledges the efforts of Dr. Janaki Bojiah with respect to proofreading of this paper.