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Zero-Carbon Cities as a New Realization of Sustainable Cities

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ABSTRACT:
Many countries are facing the problem of running-out of fossil fuels and their increasing global demand, consequently the future of cities is limited because there is no longer enough energy to run them. It is the gap between the use of fossil fuels and the exponential rise in the demand of energy which is already resulting in the energy insecurity that will be a hallmark of life and in all countries in the next decades. Thus, there is a need for zero-carbon cities which are urban areas powered by renewable energy techniques and technologies.

On the other hand, Egypt is one of the countries, in the hot arid region, that face the problem of energy and water. Another problem is the emissions of greenhouse gases arising from burning of fossil fuels to generate energy that leads to climate change and global warming.

The paper discusses the issue of planning future sustainable cities and how to apply all the new innovative renewable energy solutions to the construction and operation of these developments. It concentrates on developing a platform for a high quality of life where inhabitants can find the carbon footprint is zero. It tackles with the subject of conserving energy supplies as well as water stocks. It presents the ways of new innovative strategies which generate energy in cities in addition to waste-to-energy strategy which then runs an engine that generates electricity. The paper will analyze different cities having the same climate characteristics to achieve an understanding of the key inter-relationships between the zero-carbon strategy and the design of building and spaces.

The paper aims to achieve the criteria of designing zero-carbon cities and maximizing the benefits of sustainable technologies through an integrated planning and design approach.

By this way, the future zero-carbon city becomes self-contained and separated from the public grid. Also, it encourages architects to use all new technologies despite their high initial costs.

Conference Topic: Renewable Energy
Keywords:
zero-carbon, renewable energy technology, greenhouse gas emissions, energy efficiency, sustainability

1. INTRODUCTION:

Cities are the focal points and drivers of societal development in all countries. At the same time, they are the largest consumers of natural resources and the biggest resources of pollution and greenhouse gas emissions on the planet.

One of the most significant environmental challenges within cities is climate change. A second major concern is the environmental impact of fossil fuel use in cities, especially oil. An oil-based economy and climate change are linked: vehicle emissions contribute significantly to greenhouse gas emissions and hence global warming, (United Nation Human Settlements Programme, 2009).

Responding to climate change, sustainable design approach came from the rising concern about the environment. At the same time, sustainability concept has some threats and points of weakness. The most important threats of sustainability are the depletion of energy resources, fresh water shortage and economic wastes. However, the absence of qualified skilled workers, the high initial costs of sustainable technology and the difficulty of persuading people to accept the advanced ideas represent its points of weakness.

Accordingly, new types of cities have arisen that reduce carbon emissions on the annual basis. The paper presents the main features of zero-carbon cities that can be applied during their construction and operation process.

Finally, the aim of this paper is to provide a checklist for Egyptian architects and planners to achieve zero-carbon goals with sustainable design approaches that facilitate fulfilling energy future requirements. These design approaches include the utilization of renewable energy resources replacing the traditional oil-based energy sources and playing an important role in increasing efficiency of energy consumption in buildings. Not only this, but to achieve sustainable development objectives and in turn reduce negative impacts of pollution on the Egyptian urban cities.

2. Definition, Concept and Principles of Zero-Carbon Cities:

Depending on the technology used, generating energy whether electricity or heat will produce emissions directly through combustion of fossil fuels or indirectly through the manufacture of the equipment itself or through the transport of fuel.

Technologies such as photovoltaics, biomass, wind and hydropower produce very low levels of carbon emissions relative to energy produced directly from fossil fuels and can be thought as "*low or zero carbon technologies*."

Thus, the definition of a zero-carbon city is "*that over a year the net carbon dioxide emissions from all energy use within the buildings as a whole are zero or below*". This means that at certain times of the year a city may produce more energy than it needs, while at other times it produces less, (http://www.tcpa.org.uk).

That is to say that, "*it is the city that on the annual basis produces as much energy as it* uses." (Fig.1).This definition of zero-carbon technology is applied solely in the context of cities and is applied to the whole development rather than individual buildings.

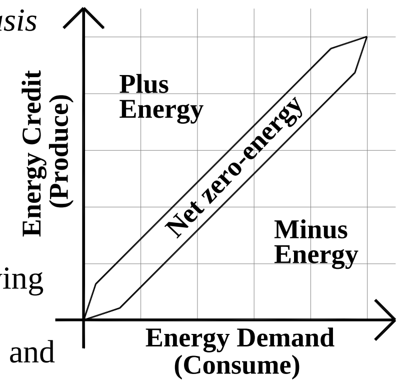

Fig. 1 Concept of zero-energy cities

The aim of a zero-carbon city is reducing carbon emissions from buildings, reducing waste, transport, materials and food emissions by 50% globally. It can be achieved by the following energy hierarchy:

1) Reducing energy-use wherever possible in the buildings and transportation sector.
2) Adding as much renewable energy as possible.
3) Offsetting any CO_2 emitted through purchasing carbon credits.

The zero-carbon goal is applied to carbon emissions arising from energy use in domestic, non-domestic, public spaces and structures in a completed development. In another context, applying the following principles over the life time of a city contributes to reducing energy use and residual carbon emissions:

1) Developing renewable energy.
2) Developing distributed power and water systems
3) Increasing photosynthetic spaces as a part of green infrastructure.
4) Improving eco-efficiency.
5) Increasing a sense of place.
6) Developing sustainable transport.
7) Developing cities without slums.

Thus, the challenge for urban planners is to apply all of these approaches together in order to generate a sense of purpose through a combination of new technology, city design and community based innovation, (United Nation Human Settlements Programme, 2009).

3. Global Vision for Emerging Zero-Carbon Cities:

Environment and energy are two sides of the same coin. Cities are the major consumers of fossil fuels which have risen from 4% of global energy consumption in the early 1900s to over 86% at present time. For all these reasons, cities play an inordinate role in greenhouse gas emissions. Mitigating CO_2 emissions and adapting to climate change are essential at the city level. It is important that cities curb waste, manage their full water cycle and contribute to renewable energy generation to become "low carbon" or "zero carbon" cities, (Ryser J. & Franchini T., 2009).

At the regional level, the buildings' sector in Egypt consumes 19.2% of the total energy consumption and about 39.1% of the total electricity consumption, which produces 10% of the total CO_2 emission, (Ministry of Energy and Electricity, 2003).

On the other hand, Egypt has a good potential of renewable resources including solar and wind power. Thus, renewable energy technologies can be considered as an integral part of the Egyptian energy policy framework.

4. Mitigation and Adaptation of Cities to Climate Change:

To keep away CO_2 emissions, all instruments are being mobilized to reduce these emissions at source and to adapt the existing emissions according to climate change policy. Achieving zero-carbon cities and contributing to climate protection require a planned change to the way in which cities are spatially configured and served. Both adaptation and mitigation measures respond to the effects of climate change, they require cities to be planned differently, (United Nation Human Settlements Programme, 2009).

The mitigation challenge is to tackle the causes of climate change through the reduction of greenhouse gas emissions. It aims at reducing the rate of carbon emissions into the atmosphere to manageable sustainable levels through the design, construction, operation and eventual demolition of a building. Mitigation measures include: promotion of lifestyles less dependent on fossil fuels and releasing less carbon into the atmosphere, more efficient use of energy, less waste and widespread use of renewable energy as an alternative to fossil fuels.

In the same way, adaptation is adjusting the building to the physical impacts of the surrounding climate and resilience against the current and predicted future effects of climate change. For example, by incorporating green space to provide shading, sustainable drainage systems, designing to prevent over heating and to avoid the need for artificial cooling of buildings.

5. Ways to achieve Zero-Carbon Cities:

There are many challenges that cities may actually face to set-up zero-carbon cities or to make the cities more environmentally friendly. There are new innovative renewable energy solutions which can be applied to the construction and operation of these cities to become an epicenter for the development and commercialization of clean energy technologies.

5.1 Urban Design Elements:

Urban planning is adapted to the local culture and climate of the surrounding region. The city reduces the carbon footprint by orienting its buildings north east to south west. This helps to minimize the amount of direct sunlight on buildings while still providing natural daylight. Building narrow, shaded passage ways, instead of wide roads, funnels breezes and helps to keep the city cool. That is a cheap way to reduce the need for not only air-conditioning systems but also for electric lighting, (Pool.R. 2009).

5.2 Water Conservation Technologies:

Water conservation is becoming increasingly important as a demand for water increase especially in hot arid regions. Reduction and reuse of water are considered as main elements to achieve zero-carbon cities. A number of conservation measures can be used in cities such as rain water collection (water capture technology) and grey water reuse.

Rainwater is collected and channelled into a catchment basin. These catchment areas can be landscaped to look like ponds increasing the aesthetics and value of landscaping effort. Collected rainwater can be then purified and reused for washing purposes.

Grey water can be recycled and treated to be suitable for irrigation and other non-drinking uses in the city, (Nady, R. 2008).

5.3 Waste-to-Energy Technology:

A small fraction of the energy needed to run the city comes from waste-based fuel. It provides a small portion of the city's electricity through the use of waste reduction measures, reuse, recycling and composting solid wastes. Such approaches to waste require new technologies and management systems that integrate public health and environmental engineering with ecologically sound planning.

5.4 Energy Conservation:

Energy conservation is taken into account when planning zero-carbon cities using active technologies such as photovoltaic plants, solar thermal collectors and wind turbines. Renewable energy enables a city to reduce its ecological footprint and it compromises a significant and important element of the urban economy.

- Photovoltaic plants can provide clean electricity for cities while producing no CO_2 emissions. The electricity supply of PV plants can be isolated from the grid supply and so provide a reliable back-up at periods of grid failure.
- Solar thermal collectors are used to minimize the energy used to heat water needed to supply the buildings of the city
- Also, wind turbines represent a main source of renewable energy and can enhance the city's efficiency in generating energy to produce electricity, (Nady, R. 2008).

5.5 Building Materials and Construction Techniques:

Local manufactured building materials are used in the construction of buildings in zero-carbon cities. Most local building materials are renewable and energy efficient. They are characterized by their durability, adaptability and low construction impact. Also, traditional building techniques are considered as a main part of the integrated design approach for achieving energy efficiency and effectively reducing internal temperature.

5.6 Carbon Capture Technology:

The principle task of the carbon unit is the development of carbon capture and storage technology (CCS). The unit's goal is to cut emissions of CO_2 annually and decrease the city's carbon footprint and consequently contribute to global mitigation, (Luomi, M. 2009).

5.7 Intelligent Transport Systems:

Cities are increasingly being designed to use energy sparingly by offering walkable transit-oriented options, often supplemented by vehicles powered by renewable energy.
Accordingly, there are other sustainability features that relate to the city's transport system. Sustainable transport can be presented in replacing cars and fuel vehicles by electric public transport. Cities with more sustainable transport systems are able to reduce their ecological footprints from their reduced use of fossil fuels as well as through reduced urban sprawl and reduced dependence upon car-based infrastructure.

5.8 Hydrogen Power Plant:

The hydrogen power plant represents a huge industrial scale installation. It takes natural gas from the grid and converts it to CO_2 and hydrogen using an amine process. CO_2 is compressed and exported while the hydrogen is fed into a combined cycle gas turbine power island to generate electricity, (Crampsie S., 2008).

6. Application on Zero-Carbon Cities: Masdar City (Abu Dhabi, United Arab Emirates)

Masdar city is a carbon neutral city of 6.5 Km^2. It is being constructed 17 Km from the city of Abu Dhabi in the United Arab Emirates. It is the world's first zero-carbon, zero-waste and car-free city which costs U.S 22 billion. The city has net zero greenhouse gas emissions with no oil or gas burnt on site. Masdar is designed in two squares, one large square and a smaller square (Fig. 2)
The city is growing to be 1,500 businesses and 50,000 residents. Of this, 30% is zoned for housing, 24% for the business and research district, 13% for commercial purposes, 6% for the Masdar Instiiute for Science and Technology (MIST), 19% for service and transportation and 8% for civic and cultural pursuits.
- In the ***first building phase*** (2009), all major infrastructures are built including the Abu Dhabi Future Energy Technology (ADFEC) Headquarters, Masdar's own University and a large photovoltaic power plant, which represent the main source of energy to provide the city with power (Fig. 3).
- The ***second building phase***, the larger square of the city is to be completed.
- The ***third building phase***, the smaller square of the city (Fig 4).
The whole city of Masdar is expected to be completed by 2015, (http://www.wspgroup.com).

Fig. 2 Masdar City is designed in two squares

Fig. 3 The larger square contains all major infrastructure

Fig. 4 The smaller square of Masdar city is expected to be completed in the third phase

6.1 Masdar Zero-Carbon Features:

6.1.1 Culture and Heritage:

Masdar city draws its inspiration from the Traditional Arabic cities environmental and climate response to climate change (Fig. 5). The city reduces the carbon footprint by developing in a compact area (Fig. 6) that allows for easy pedestrian movement and expands the comfort zone of the city through the control of sun and wind to create the highest sustainable quality of life. Narrow, shaded streets reduce the outdoor temperatures by as much as $20c^o$ making it possible to comfortably enjoy the outdoors for a longer period of time (Fig. 7). Carefully planned landscape and water features also aid in reducing the temperature and enhancing the quality of the street (Fig. 8), (Crampsie S., 2008).

Fig. 5 The planning of Masdar City is similar to the Traditional Arabic

Fig. 6 Masdar City is characterized by its compact design

Fig. 7 Narrow shaded streets in Masdar City

Fig. 8 Masdar City is characterized by its landscape and water features

6.1.2 Water Conservation (Sustainable Water):

Water is an increasingly sparse source in Abu Dhabi. Accordingly, Masdar will be an oasis in the desert through the use of brackish and other local water resources, the application of advanced water treatment technologies, recycling and overall the reduction of water demand (Fig. 9). Masdar city has a solar-powered desalination plant, around 80% of water is recycled on-site through different mechanisms, (Pool.R. 2009).

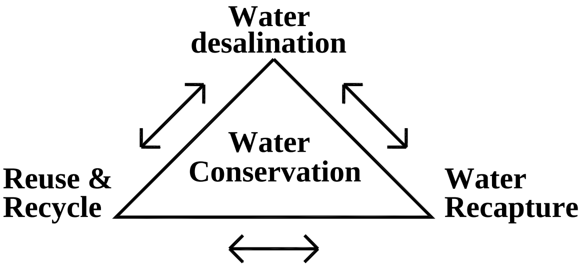

Fig. 9 Sustainable water technology

The intention of Masadr city is to reuse water as many times as possible. For instance, leftovers from watering crops will be captured through irrigation recovery.
This mechanism works by collecting leftover water from the top soil, after irrigation through an underground collection system. The collected water can then be used for other purposes.
Landscaping within the site is irrigated with grey water and treated waste water is produced by the city's water treatment plant.
Dew catchers, rainwater harvesting and electronic sensors to detect cracked pipes, are all to be used, and also maximizing the use of local water resources.

6.1.3 Waste-to-Energy Technology:

Another objective of Masdar city is zero-waste through the use of waste reduction measures, reuse, recycling, composting and waste-to-energy technology. As a part of the zero-waste strategy, biological wastes are converted into renewable "E-fuel", a fossil fuel replacement or used to create nutrient rich soil and fertilizer while everyday waste is sorted and recycled, (Crampsie S., 2008).

6.1.4 Energy Conservation:

According to Masdar, the city requires just 200 MW of installed capacity as opposed to more than 800 MW for a similar-sized conventional city. In addition, the city is entirely self-sustaining in terms of energy needs. Masdar has several main power sources to meet the energy that the city demands.
To generate zero-carbon energy to build the city, a temporary photovoltaic power plant is installed on-site before any building commences (Fig. 10). As the city is near completion, the photovoltaic power plant will be transferred to permanent structures within the city.

In addition, there is a solar thermal power plant using parabolic troughs (Fig. 11) which work on the principal of concentrating solar into steam. The tower contains molten salt and the surrounding solar concentrators or mirrors (with heliostats) redirect sunlight to the tower. The tower will generate steam that turns an electricity turbine to create energy. The salt is there to keep power going for about 15 hours even when there's no sun.
There is also a wind energy farm located in the land surrounding the city (Fig. 12). Any excess energy generated is supplied to the national grid. Abu Dhabi predicts that such technology will reduce electricity by 25% relative to current similar-sized communities.

Fig. 10 Masdar's photovoltaic power plant

Fig. 11 Masdar's solar tower

Fig. 12 Wind farms in Masdar City

6.1.5 Transport System:

Masdar is one of the world's first zero-car city. Due to Masdar's pedestrian-friendly design, walking and bicycling are expected to be the city's most popular forms of transit. Pedestrian networks in the city are also supplemented by two electric transportation systems designed efficiently to convey people further distances. The first system is a Light Rail Transit (LRT) which connects Masdar to Abu Dhabi city, the adjacent international airport as well as other surrounding communities, (http://www.courses.cit.cornell.edu). The second transport system developed for use in Masdar is an underground Personalised Rapid Transport (PRT) system (Fig. 13) which replaces buses and trains with smaller vehicles designed for four to six people. The system is the world's first personalised electric transport system. Masdar's planners expect the system to use less energy than conventional mass transit and it will be more convenient, too. In a PRT system, several small vehicles, often called *pods*, are kept waiting at each station. An individual or a small group boards one and selects a destination, the pod proceeds automatically to the destination without stopping. The vehicle follows a track, which is connected to stations by on-ramps and off-ramps, and a computer controls how the pods enter and exist the stations. The ramps allow the individual pods to make stops while others continue along the main track at top speeds.

Fig. 13 Masdar's Personalised Rapid Transit (PRT)

6.1.6 Carbon Capture Facility:

A primary goal of Masdar is to drive the creation of low carbon economy in Abu Dhabi and the region. Its Carbon Management Unit is spearheading the development of CO_2 emission reduction projects, including the development of carbon capture storage (CCS) technologies and the creation of national CCS network for enhanced oil recovery. The plant consists of a carbon capture facility and a natural gas reformer which converts 100 mft^2/d of natural gas into hydrogen and CO_2. The hydrogen generates low-carbon electricity whilst the CO_2 will be captured and used to replace the natural gas that Abu Dhabi currently injects into oil fields to maintain operating pressure and enhance oil recovery. According to Masdar, a fully developed CCS network could reduce the UAE's annual CO_2 emissions by 40% while simultaneously increasing oil production by 10%, (The Chemical Engineer, 2008).

6.1.7 Building Materials:

Buildings within Masdar ensure the latest use of energy efficient technologies and smart design. Throughout the construction process, great measures are taken to maximize the amount of recycled and certified sustainable building materials (Fig. 14). The majority of building materials used in Masdar have a high thermal mass, resulting in high levels of insulation for the city's buildings. Building designs incorporate heavily insulated walls with thin layers of copper foil on the outside to keep heat out and prevent residents reaching for air-conditioning, (Bullis,K. 2009).

Fig. 14 Masdar's Headquarter is built with energy efficient materials

6.2 Observations and Shortcomings resulting from Masdar City:

The project is supported by the global conservation charity (WWF) and the sustainability group BioRegional. In response to the project's commitment to zero-carbon, zero-waste and other environmentally friendly goals, (WWF) and BioRegional have endorsed Masdar City as an official 'One Planet Living' community, (http:// www.resorcesmart.vic.gov.au).
Despite being One Planet Community, Masdar unsustainability is mainly related to how it was designed with little understanding of the social context an it involves constructing a brand new city in an intensive place, the desert. The Masdar project, even though it will be carbon neutral, requires massive amounts of energy, land and water to construct and sustain. Another concern is that the funding for the project comes from very unsustainable means. The $22 billion cost of building Masdar is funded almost entirely through the revenues from oil and gas exports, which fuel greenhouse gas emissions throughout the world.
On one hand, it is observed that people in Masdar will commute in ordinary vehicles and there are numerous car parks that surround the city for commuters and visitors to park their cars before entering the city with a short distance to the nearest transport link and amenities, (http:// www.wspgroup.com).
Also, being located in the middle of the harsh desert climate, providing Masdar city with water is one of the most difficult tasks. Thus, highly efficient water system is a key element of Masdar's sustainability plan. The city will drive all of its water from a desalinization plant located outside the city which will run on solar power to get potable water from seawater. After this water has been used, it will be collected and processed so that it can be used as grey water for irrigation and so on. Masdar planners are trying to achieve a 60% reduction in the overall water consumption.
Furthermore, in order to become a zero waste city, Masdar will use waste incineration, recycle or reuse plastics and metals etc. Also, food and other biological wastes will be composted to make fertilizers and rich soils for growing crops to feed the city.
As a result, there are several major flaws with the sustainability of Masdar city and its usefulness as a model for other cities. While these critical points are undoubtedly correct, no project is perfect and no one can deny that Masdar is a visionary project that will help to develop green technologies. Even if the city as a whole is not useful for existing cities to

model, they can model parts of Masdar, like the PRT system or the wide spread deployment of solar and zero waste technologies. Many of these technologies are in their infancy and if Masdar can show that they will work and are cost effective, these technologies can then be deployed on a larger scale throughout the world.
Finally, the goal of the new city is to set new standards and to develop new clean and sustainable technologies that can be transferred to other cities in Egypt for example.

7. Could be another Zero-Carbon City in Egypt??

El Gouna is a private self-sufficient city built on 10 Km on the Red Sea coastline in Egypt located north of Hurghada. Established almost 20 years ago, the city is now populating between 12,000 to 15,000 permanent residents and visitors from all over the world.
El Gouna city provides a full range of facilities and services, such as a mosque and a church, transportation, schools, healthcare and security, giving the community a feeling of comfort and convenience. El Gouna's overall uniqueness is in its harmony as a result of careful planning, superb architecture and competent management which have ensured that the city's many attractions are contained in a beautiful and aesthetically unified setting. The city's architecture brings together a blend of traditional and modern elements.

7.1 El Gouna Sustainable Features:

7.1.1 Sustainable Site:

The city's design is compact (Fig.15) and is characterized by the visibility of its entrance. It has been taken into consideration that the character of the city development is derived from the traditional rural Egyptian context (Fig. 16). Buildings are covered by domes and vaults (Fig. 17) in order to provide the interior with moderate climate, (Nady,R. 2008).

Fig. 15 El Gouna City is characterized by its compact design

Fig. 16 The identity of El Gouna City is inspired from the rural Egyptian context

Fig. 17 El Gouna City is characterized by the Egyptian vernacular architecture

7.1.2 Water Management System:

El Gouna produces its own water by desalinating sea and well water and utilizing treated waste water for irrigation of the golf course and greenery throughout the city. Also, the grey water existed in the city is recycled and treated to be suitable for irrigation.

7.1.3 Recycling and Waste Management:

El Gouna city practices garbage separation and recycles materials locally. The city's waste and garbage are sorted, separated and recycled at source in colourful amphora shaped bins (Fig. 18). Each bin is used for a specific material, for example, one bin for plastics, cans, glass and paper. Plastic is melted down and made into plastic bags, clothes, hangers or paving stones. Glass goes to brewery, whose malt residues are fed to the turkeys.

Fig. 18 Colourful bins for separating wastes

7.1.4 Energy Conservation:

The city achieves a reduction in the consumption of non-renewable resources by exploiting the wind power found in Hurghada. Some of the energy used in the city is generated using the horizontal wind turbines found in farms around the city (Fig. 19). The turbines are located in a good wind regime which offers a good condition for the operation of wind turbines. The turbines are placed on shore i.e. more than 3 Km from the shoreline, (Nady, R. 2008).

Fig. 19 El Gouna horizontal wind turbines

7.1.5 Building Materials and Construction Techniques:

The buildings are constructed with locally manufactured materials such as clay and natural stone with thickness from 50 to 60 cm (Fig. 20) such building materials conserve energy and improve all environmental practices. The typical wall construction minimizes noise pollution from different resources as well as reducing the indoor temperature. Buildings are covered by domes and vaults (Fig. 21) providing the interior with moderate climate. Also, landscaped courtyards (Fig. 22) maximize the cooling effect inside the buildings, (Nady, R. 2008).

Fig. 20 The building of El Gouna City are constructed from local materials

Fig. 21 El Gouna buildings are covered by domes and vaults

Fig. 22 Landscaped courtyards in El Gouna City

7.1.6 Sustainable Food:

Around El Gouna area, Egyptian organic farmers grow a variety of crops, including fruits, vegetables, cereals and spices as well as non-food crops including cotton and medical plants. Also, food waste is eaten by the sheep and cattle, (http://www.greenstarhotel.net).

7.2 Observations resulting from El Gouna City:

El Gouna city has been awarded the prestigious Green Star Certification. It has succeeded to achieve the natural, cultural and technical images of sustainability. El Gouna community proves how successful a multifaceted community can be. In another context, cities like El Gouna can be converted into a zero-carbon city by applying zero-carbon design features and planning strategies. These strategies are not very different from El Gouna sustainable design characteristics. However unfortunately, increasing the initial costs of applying renewable energy technologies and zero-carbon techniques represent a financial barrier and a technical constraint of turning existing cities like El Gouna into a zero-carbon city.

8. Zero-Carbon Concept Versus Sustainability:

Table. 1 A comparison between zero carbon and sustainability concepts

Point of Comparison	Masdar City (Abu Dhabi, United Arab Emirates)	El Gouna City (Hurghada, Egypt)
1) Zero-Carbon	Carbon capture facility and a natural gas reformer, reducing CO_2 emissions and increasing oil production	N/A
2) Zero-Waste	Reduce, reuse, recycle, compact, waste-to-energy	Sorting, separating, recycling and reuse
3) Sustainable Transport	Zero-cars, walking, biking, light rail, personal rapid transit (PRT)	N/A
4) Local Sustainable Materials	Very efficient with a high thermal mass	Clay or masonry bearing wall construction
5) Local Sustainable Food	Compost for soil, grey water irrigation, green belt of agriculture	Organic crops, wastes are eaten by animals
6) Sustainable Water	80% of water reused. All water derived from a solar powered desalinization plant	A water treatment station has been used to reuse water
7) Natural Habitats and Wildlife	Mitigation for any impacted plant and animal as an effective conservation	Underwater protection and beach clean-up
8) Culture and Heritage	Compact pedestrian walkways, narrow shaded streets, landscape and water features	Landscaped courtyards, domes and vaults
9) Equity and Fair Trade	Pledging to pay all employees fair wages in accordance with international labour standards	Broad range of income levels
10) Health and Happiness	Meeting the needs of the people and the environment	N/A
11) Energy Conservation	Photovoltaic power plants, solar thermal power, large wind turbines, geothermal ground-sourced heat pumps and hydrogen plant	Wind farms using horizontal wind turbines (HAWT) which are located onshore

The previous table shows the principles of zero-carbon cities according to One Planet Living to provide a checklist for Egyptian architects and planners to achieve zero-carbon goals of future cities in the Egyptian context

9. The Future of Zero Carbon Cities in Egypt:

The aim of zero-carbon cities is to reach a balanced ecosystem in Egypt through dealing with the urban environment as a part of the ecosystem. Hence, the proposed strategy presents an accelerating public awareness regarding the importance of environmental quality and energy reduction in future Egyptian cities. This awareness is oriented to utilization of renewable energy resources and conserving water supplies in addition to recycling wastes. Within this process, all media facilities would be useful for increasing the public awareness to achieve the zero carbon strategy in the Egyptian context.
There are two types of renewable energy systems that are most suitable for the Egyptian environment, solar and wind energy. These renewable energy systems could efficiently be enhanced in the city's development.
Zero carbon cities emphasize that the renewable energy methods are essential for the planning and the design of the city's buildings, their operation and management.

10. Conclusion:

10.1 General Findings and Outcomes:

- A zero-carbon sustainable future is not just an aspiration. Around the world, it is becoming a reality as progressive thinking individuals, businesses and government organizations to change the way they live and work to meet the challenges of resource depletion and climate change.
- In the master plan of a zero-carbon city, building designs and the zero-carbon strategies will need to offer an integrated solution in multiple challenges including design for reduced energy demand and for comfort and climate change adaptability, flexibility to integrate future low carbon techniques.
- Leading a community towards zero-carbon technologies is ambitious and necessary. Fortunately, many cities have begun this innovative kind of future oriented process (like Masdar city). Based on the experience of zero-carbon projects in many countries, it is important to improve, innovate and modernize policy and management activities.
- Achieving zero-carbon cities in Egypt is to compromise between the sustainability concept and zero-carbon to reach a balanced solution that comply with the capabilities, the economic barriers and the local culture.
- A zero-carbon city creates a model for eco-design worldwide. It is characterized by some points of strength such as minimizing the ecological footprint, developing low carbon economy and making people aware of their carbon impact.
- Zero-carbon strategies have positive opportunities through self-sustaining in terms of energy needs, development of carbon capture and storage technologies and encouraging energy efficient designs.

10.2 Recommendations:

- There is a call for rethinking of the definition of zero-carbon cities, as in the present era, it is vague in its current format without clear and structured guidelines.
- Compulsory adoption and a step to change in building and planning practices are the most suitable ways of achieving the goals of zero-carbon cities.
- There is a substantial amount of education that needs to happen for the general public to appreciate the benefits of zero-carbon cities.
- It is necessary for the government to act upon this growing demand for zero-carbon cities and legislate to create a national market for zero-carbon technologies in cities.

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