Masdar - The Sustainable Desert City: A Theoretical Mirage or A Realistic

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Masdar - The Sustainable Desert City: A Theoretical Mirage or A Realistic Possibility?

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Abstract

Masdar City, currently being developed in Abu Dhabi and designed by Foster + Partners, a high-profile British firm of architects, sets a groundbreaking example of a new breed of eco-cities. The city's birth has taken on an environmental stance. Having recently completed its first phase of construction, the emphasis of the development is principally based on sustainability, using traditional walled city planning and existing technology to achieve a net zero-carbon and zero-waste development. To achieve carbon-neutrality, the design team has employed a series of innovative environmental design strategies and integrated planning principles. This paper presents these strategies and discusses the project in relation to its social, economical and environmental contexts, and considers prospects for the viability of building in the desert and its global impact on sustainable urban development of the future.

Keywords: *Masdar City, Desert Cities, Sustainable Urban Development*

1 The Desert Environment and Desertification

1.1 Introduction

Whilst parts of the world are experiencing wetter weather, other areas are experiencing hotter and drier weather. These global climatic changes are accelerated by human activities arising from carbon emissions as well as many other harmful greenhouse gases and pollutants associated with motorisation and industry. The degradation of existing drylands is further complicated by the increased mismanagement of human activities such as increased deforestation and grazing, resulting in more of the earth's surface turning into deserts, therefore accelerating the process of desertification. (Le Houerou, 1996; Millington and Pye, 1994).

Although desertification could be prevented or reversed if drylands were managed properly, it is interesting to speculate whether these areas, having lost their economic value as farming and grazing lands, could still usefully support human life, albeit on an urban basis. Can we begin to build green desert cities on these degraded lands to revive its capacity to support life again? Some schemes have been employed to stop this process of desertification - the better use of trees in Northern Kenya (Muga, 2009) and the growing of straw grids to stop the spread of deserts, sand fences in Middle-East (http://www.pubs.usgs.gov). It may be relevant to pose the question to whether construction of a city can have a similar remedial effect to stop the extent of desertification.

Taking into account the current problem of over-population that is putting a strain on earth’s resources, the success of a sustainable desert city survival will have an implication on how the desert can be used to solve the global problem of overpopulation. Since drylands support a fifth of the world population (Barker, 2002), what happens to the desert has implications on human existence on the planet. If a new desert city can be planned to be sustainable, built sustainably and can operate sustainably, building new sustainable cities may in fact have a positive impact on the desert environment.

1.2 Cities in The Desert

Many civilizations have existed, lived and survived in the harsh inhospitable desert environment throughout centuries in many different parts of the world - the native North American Indians of the Mojave Desert, tribal people of the Atacama Desert in South America, the Bedouins that thrive in and around the Sahara Desert in Africa and the Aborigine peoples in the Gibson Desert of Australia.

For various socio-economic reasons, settlements and cities have also risen out of the desert sands - Las Vegas, Phoenix and Dubai, for example. Recently, within the Middle East, an impressive breed of cities has been built and many are planned or are in the process of construction. For example, The King Abdul Aziz

City for Science and Technology, Qatar's Education City, Egypt's Mubarak City of Scientific Research and Technological Application and Bahrain's Higher Education City (Murray, 2009).

The question of city building in such harsh, dry and inhospitable environments remains debatable. Taking into account the energy it takes to build and run a city in the middle of a desert is a concept that defies conventional logic of human settlement making. As such, desert cities are often not considered a sustainable move.

However, one city in the making has ambitions to change this - Masdar City in the UAE is a city that aspires to be sustainable and net carbon-neutral - the first city in the world to do this.

2 Methodology and Limitations

The analysis of sustainable city building is based on a case study example of a brand new city under construction and specifically Masdar City. This paper will be based upon limited secondary data that has been published about the city and its development. As the city is still under construction, there is limited amount of published work used to form the basis of critical evaluation. As such, an interview with the Senior Partner and Project Architect Director for the project was conducted to provide an overview of the project. This paper has been written about this new project to raise awareness of a revolutionary sustainable desert development, to provoke interest and to encourage critical debate within this area of sustainable architectural and urban design.

3 The Birth of Masdar City

> *"I think what is most special about this city is that it is not just any normal city; it is a city of green buildings, green research and that's what's most special about it. I think the fact is, there are a lot of cities being talked about in the world, carbon-free cities and so on, but this one is a real one and it's being built! In fact, the first phase of the Masdar Institute is nearing completion!"*
>
> Gerard Evenden, Senior Partner at Foster + Partners when asked about what is most unusual about this city during the interview.

Masdar means "*source"* in Arabic. The city's conception is based on the need to diversify an economy largely based on fossil fuel which currently generates approximately 70% of the gross domestic product of the Emirate (Reiche, 2009).

The city is being built with the ambition of being the first net-carbon and car-free city in the world.

The city, to be built on existing desert land, is situated 15 km east of central Abu Dhabi adjacent to the airport, in the Arabian Peninsula. The city, whose aim is to become "the silicon valley for clean, green and alternative energy" (Masdar Initiative, 2008), measures 6 square km and is designed with numerous sustainable features.

When completed, the city will house 50,000 residents. It endeavours to attract 1500 businesses in renewable energy supply and research and development, providing jobs for its residents as well as a further 40,000 commuters who would be transported into the city by light rail transit (LRT) which also connects the new city to the airport (Masdar Initiative, 2008).

The Masdar Initiative was first instigated by His Highness Sheikh Mohamed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi. The project is a wholly owned subsidiary of the Mubadala Development Company. The project, developed by Abu Dhabi Future Energy Company (ADFEC), is wholly owned by the government of Abu Dhabi (Crampsie, 2008).

The designers looked to ways of inventing a new city which fundamentally caters to the needs of the users, and provides a high quality of life, without compromising standards of modern day living. The project will be constructed in seven phases.

Foster + Partners were approached to design the city in a 2-stage competition. The office was appointed to become project architects after the first stage of the competition. The site for the new city was offered by the clients.

> *"One of the aims of the Masdar Initiative is about connecting people together in order to move the technology of renewable energy forward. We realized this in terms of the team structure - by bringing the right people together. They (the clients) thought it was a good basis to move forward and we also had shown them the idea of our design, which in terms of masterplans is very important in showing the balance of land and development. We cannot develop all the land if we are looking to support development. We have to look at the ways in which we do it, we have to look at the way people live- that was really the driver…What we said was first of all, we should look back and look at people and look at the way we create spaces between buildings and create spaces for people."*
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> Evenden, when asked what was the main design driver of the project and the project set-up.

Figure 1: A Bird's Eye View of Masdar City. Can such a vision become a reality? Image courtesy of Foster +Partners

3.1 The Urban Morphology

The orientation and layout of the city is a direct response to sunlight. One of the greatest problems facing survival in any hot and dry desert environment is how the human settlement deals with the heat, dryness and exposed nature of such geographical locations.

The direction of the urban grain is twisted to an orientation that maximizes shading in the streetscape, subsequently minimizing daytime heating on street level to create cool public spaces for people to use. The streets are also made narrow to replicate maximum shading conditions in traditional Arabic cities such as Aleppo in Syria (Craft, 2008). Interestingly, these are not revolutionary strategies; rather evolutionary common-sense developed over the centuries by Arab city builders to achieve thermal comfort in the hot, arid desert. The orientation of the urban grain also imparts a variation of the street character by its ever-changing light levels during different times of the day. The tight and dense nature of the planning principles of a walled city helps to protect the city from desert sand and grit blown in by the desert winds.

Shaded courtyards are created by the use of blinds and solar shading. The shading helps to further reduce energy loads of the building which are supplied from renewable resources, such as solar power, to keep the development net carbon-neutral. Appropriate elevations of buildings are also loaded with photovoltaic cells which also provide shade to the spaces below.

> *"The idea is that you can move around underneath. The important thing is that we've got pedestrians and communities above, and because of this relationship of one building to another that creates shade, pedestrians can walk around the city in the shade. If you made everything wide enough for the transportation system to move around on the same level as the people, then you wouldn't have the benefit of that relationship between buildings. And if you don't get this relationship between buildings right, and if you don't get the passive systems of the buildings working correctly, you can't reduce energy load in the building. You have to reduce energy loads in buildings between about 60% and 70% from the normal, from today's level if you're going to stand any chance of producing energy from renewable sources to power the buildings."*
>
> *"The city is lifted up on a deck. Basically what we have done is that we separated the transport from people. The city is raised 7 meters in the air and all the traffic and pedestrian activities occurs underneath. ……We don't want it to be a walled city- it's not a defensive city- it's trying to open up to the outside. We are trying to make a vertical separation. It is permeable on ground level by the transportation system coming to and moving around inside it."*
>
> Evenden explaining how traditional principles of the walled city helps to reduce energy loads of buildings and separates the different modes of transportation in the design.

The city is raised 7 meters above ground on a podium that separates transport from pedestrian movement. The transport system is located in the lower level whilst pedestrian movement is designed to take place on the upper level. This typology is similar to other "plinths" that appear in other historic Arabic cities such as Shibam in Yemen, on which it was built to protect the city from floods and from human attack.

3.2 The Masdar Institute

The first phase consists of the Masdar Institute which is a collaborative educational establishment set up with The Massachusetts Institute of Technology (MIT) to offer courses and research facilities related to green energy. 40,000 foreign students and researchers are expected to be in residence in Masdar City. The research institute seeks to further knowledge on alternative building technologies by using the construction of the city and monitoring it to enhance research and development.

Thermal comfort requirements to live, work and play comfortably, in the harsh desert environment, are met by new technological solutions derived, interpreted and developed from traditional principles evolved over centuries in

Arab civilization and settlement architecture. The same challenges of modern city living are met by a series of creative and more sustainable means.

3.3 Sources of Renewable Energy

The project includes the construction of a 10MW solar farm that will provide energy for the construction work. During the interview with Gerard Evenden, Senior Partner and Project Architect from Foster + Partners, it is learnt that the solar farm is currently producing excess energy where this is returned to the national grid. The energy needs of the city will also be supplied from wind and bio-fuel sources.

3.4 Transportation Strategy

> *"I wouldn't call it car-free - Masdar has a transportation system. What we're looking into is the future. Cars are petrol-driven. We are not trying to exclude convenience. We're trying to bring convenience using all the new forms of transportation and what the new forms of transportation might be in the future. I think Singapore is a fantastic example - where the public transport is extremely efficient and where the population actually uses it, because it is efficient. We need to look at ways to constructing efficient and convenient transportation system that may take many different forms in the future. But what we're doing is keeping out the petrol driven vehicles that are producing all these carbon. And actually when you look at burning oils and car fuel, it is a terribly inefficient way of using fuel."*
>
> Evenden, talking about the new form of transport at Masdar City.

Masdar City will be the world's first car-free planned city. The city will be linked to Abu Dhabi City and the airport, as well as other nearby communities with Light Rail Transit System (LRT), essentially a carbon-free mode of transport running on electricity.

Pod cars as part of the futuristic PRT (Personal Rapid Transit) system will shuttle people within the city. The small cars, each of which seats up to six, run on a recyclable lithium-cadmium battery, whose charge can be topped up while the vehicle is waiting at the station. The cars mechanically run on repelling magnetic forces in a multi-level, barrier-free environment. 3000 pod cars will make up to 135,000 trips per day. The journeys will be planned and time-tabled sophisticatedly to prevent traffic jams, eradicating stresses of city travel. These pod cars journeys will last a maximum of 7 minutes between any of the 83 stations at any point within the city. The city recognizes the convenience that is

Figure 2: Shaded Courtyards and Walkways within the development paints a desert idyll of tranquility. Image courtesy of Foster +Partners

provided by private transport, but provides this in a more environmentally friendly format.

Masdar City has also been designed extensively with features such as shaded courtyards and walkways that encourage a personable and carbon-free means of moving about around the city such as walking and cycling.

3.5 Water Management

> *"We are also looking at the separation of black and grey water and the recycling of water for irrigation and so on. All the water we use is desalinated because it has to be able to drink. There is no potable water available. What we have to do is to reuse the water that is desalinated as many times as we can in order to create the irrigation etc."*
>
> Evenden, speaking about water management issues in Masdar City.

One of the greatest problems facing a settlement in the desert is its shortage of water. Sea water will be desalinated using solar power for use as potable water in Masdar City. To conserve water, grey and black water will be separated, recycled and used in irrigation applications.

3.6 Greenery

> *"We're looking at low water usage and low water using plants. In the past, people brought in species from outside the country which are high water using plants. A lot of them come from places like Singapore and Malaysia, and so what we're looking at is types of plants and also the individual water usage of each plant."*
>
> Evenden, when asked about the choice of plants in the city planting scheme.

The benefits of a green environment to human existence are commonly known. Plants and vegetation will be introduced to create a comfortable environment for humans to live in. Studies of different plant species are being conducted. Plants, mostly species indigenous to the desert environment, have been selected and used to create a green living environment.

3.7 Waste Management

Vacuum waste technologies are utilised to eliminate the need for landfill. Waste will be categorically separated. Bio-waste will be composted and the end-product used to enrich farms and plantations located at the periphery of the city. Recyclable waste will be recycled and the remaining wastes will be used in a waste-to-energy plant. During the construction process, all steel, concrete and wood will also be recycled and reused. (Masdar Initiative, 2008)

3.8 Energy Recovery

A natural gas reformer and carbon capture facility that transforms 100 million cubic feet a day of gas produced by Abu Dhabi National Oil Company (ADNOC) into hydrogen and carbon dioxide is planned. The recovered gas is then sold back to ADNOC (Gavin, 2009).

4. Architectural Design Planning and Sustainable Urban Strategies

4.1 Passive Cooling Strategies

Two Green Linear Parks are designed to run across the city to maximize air flow across the city in relation to land and sea breeze influxes. They act to funnel fresh cool air into the city and drag stale hot air out of the city.

"It does so by funneling air and allowing a greater amount of air through. We're looking at the areas at the edge of the city - denser towards the centre of the square and less dense towards the edge. As air comes across the desert into the city, we want it to be mixed up and moved around and pushed down into the streets in the centre. The other thing that happens is that you have this situation when you deliberately change the direction of the streets. It's not a grid plan, If you create changes in direction in the street, what happens is that there will be a change of direction - air movement becomes turbulent and an eddy effect is created. Therefore, the air gets flushed out and thrown out of the street and so you get this cooling effect. In terms of the wind tunnels and these effects, they are actually working." explained Evenden, Senior Partner, Foster + Partners.

Passive cooling strategies such as wind towers and wind gates, evolved from ancient Arabic tradition of city building, are integrated into the urban design. At the time of writing, the first wind tower is being constructed.

"There are some wind towers to achieve passive cooling in the public areas. In The Masdar Institute, there is a wind tower. We are not trying to collect any wind energy particularly. Half of the centre's energy might come from wind, but the problem with the wind in Abu Dhabi is that it is very sporadic and not consistent, not particularly strong and actually the best source of renewable energy is, of course, solar energy." Gerard Evenden Senior Partner, Foster + Partners.

Interestingly, the early principles of methods of passive cooling such as wind tunnels and wind gates are still being deployed in today's high-tech construction project.

Figure 3: A Green Linear Park of the city. Image courtesy of Foster +Partners

4.2 Construction Materials and Process

The environmental credentials of building are being monitored with regards to the choice of building materials for construction. Building materials are recycled at a recycling plant on site.

4.3 Mechanical Ventilation: Air-conditioning

The Masdar Institute contains numerous scientific research laboratories that require specialist ventilation. In fact, some of these technical areas will require 24 hour of air-conditioning. These mechanical ventilation systems will be powered by electricity derived from the sun via solar farms which offsets carbon consumption to maintain net carbon neutrality.

5. Critiques of the Project

Some critics believe that even if Masdar City is able to self-sustain on a net zero-carbon, zero-waste basis, building in a desert environment that is hot, dry and ultimately unsuitable for human existence, does not represent sound sustainable practice. In such an inhospitable environment, any desert city will require much more resources such as land, water and energy to construct and sustain. The hot and dry desert environment also requires much more energy for the desalinization of water for irrigation and for human consumption. It would also inevitably require more energy to run and cool such a city. (Stilwell and Lindabury, 2008).

A further fundamental criticism made of Masdar City concerns the fact that the UAE relies heavily on crude oil and gas exports. The US$22 billion needed to build Masdar City is, therefore, considered as being primarily funded by an

unsustainable industry (Stilwell and Lindabury, 2008). Skeptics might also view Masdar City as just another record-breaking projects built within the Emirate today, an unfortunate contradiction to the driving ambition of becoming net carbon-neutral to comply with the One Planet Principle. Moreover, at US$22 billion, this project is extremely costly, few countries would find it easy to finance the construction of such a highly aspirational city.

Stilwell and Lindabury (2008) cites the insignificance of Masdar City in reducing greenhouse gas emissions of the UAE due to its size in comparison to the other cities of the Emirate cities. According to the Living Planet Report 2008 published by The WWF (World Wildlife Foundation), UAE has the biggest ecological footprint in the world. Masdar's predicted population of 50,000 (Masdar Initiative 2008) is small compared to Abu Dhabi City's population of 650,000 in 2005. The population of UAE is expected to grow rapidly with the development of 2 new industrial centers, new developments and tourist attractions (http://www.soe.ae). With this many development built and an expanding population of inhabitants, the carbon-neutrality created by Masdar is thought of as being quickly offset by the development by the rest of the UAE.

As Masdar is planned on walled city principles, one can easily draw similarities between other historical cities such as Shibam in Yemen. The vertiginous Yemeni City is built in the 16th century on a plinth to protect themselves from attack of the weather and other people is the oldest surviving city. The tall buildings in this Unesco World heritage site was built from adobe made from the earth nearby and baked under the sun. This is a true example of the local use of materials. The urban form also creates shadows within the fortified city to enable the inhabitants to be able to walk comfortably in the scorching heat of the desert. Many building openings and mechanisms of passive cooling have been incorporated within the design of the various dwellings in the city. Although these 2 cities are similar in form, the technologies used to create these built forms are very different. This raises the question of whether Masdar could have employed such low-tech building systems to push the mantra of carbon footprint reduction to its limits. This raises the question of being carbon neutral versus net carbon neutral developments - and questions the validity of importing non-local materials such as glass and steel into the desert to construct a brand new city.

Masdar has a strategic economic set-up, taking best advantage of its associations with a petroleum-based economy. By diverting economic emphasis to a knowledge-based industry of higher education and research of green alternative energy, the construction project acts as a testbed for new ideas and new technology. The new city is set to attract a new breed of well-educated intelligent émigré, drawn to the attractive standard of living, quality of life and an environmentally-conscious lifestyle offered by the city. However, one might question if this may in fact create a gated enclave of specialist residents detached from the rest of the country. Physically, with the edge of the city as defined as it is; although not walled, the city does not engage with the rest of the land. How

the city assimilates into the rest of the country socially poses a valid cause of concern.

An alternative perspective highlights the possibility of building on areas previously deemed economically unviable such as deserts and newly desertified zones. On our planet, the effects of global warming are having an incremental effect on the areas of dry arid desert being formed (Edwards, 2005). With desertification being accelerated by human activities such as over-grazing, building new cities in these newly desertified areas may have a positive impact on the desertification process, stop or even reinstate these lands into economically sustaining land which supports human life again. With an increasing global population and with resources of our planet stretched to support our rapidly expanding population, the results of this experimental desert city is eagerly awaited upon its completion in 2016.

Encouragingly, Masdar City is of an unprecedented scale in comparison to historical examples of eco-towns and eco-settlements such as the Vauban area of Freiburg in Germany (population of 5,000 (www.urbed.com)) and The Bo01/ Vastra Hamnen in Malmo, Sweden (10,000 inhabitants, (www.malmo.se)). Comparatively, as Masdar is of unprecedented scale, it brings global attention to the significance and issues of sustainable urban development.

In addition, the beginnings of Masdar is seen as a hopeful sign of the commitment the Emirate States is offering to address the pressing issue of sustainable urban development. The conditions have been favorable in the case of Masdar - it has the financial backing, and importantly political vision, leadership and support (Masdar Initiative, 2008).

Fundamentally, a city is not defined just by its collection of buildings, or its cutting-edge environmental architecture. A planned sustainable city will only be successful when its citizens embrace this lifestyle change. This can be most effectively achieved by generating education opportunities and developing this awareness into a culture that can be passed down from one generation to another. The citizens, the residents and end-users of the city will ultimately give Masdar City its character and finesse. The citizens of Masdar is expected to largely consist of expatriates within the 6 square km area. This population is expected to hybridise into a new culture of a mix of high-technology expertise, green awareness and cosmopolitanism.

Excitingly, Masdar would become the second city in the world without the motor car (after Venice, Italy). The development postulates the future of public transport in an urban setting. If this works, the green transport plans may become the common blueprint for transportation of future cities and inform how older cities might retrofit their infrastructure to accommodate green modes of transportation. Although the city has done without the use of motor cars, the ease and convenience of city travel is not removed. This is an interesting observation that a city is reverting to a historical model not designed for the motor car, as seen in many medieval towns and cities like The Shambles area in the city of

York in England where the roads are narrow and were not built to accommodate vehicular transportation.

Learning from the designers, Masdar is designed not to compromise human comfort or reduce the experience of modern city living - the city is, afterall, built for human habitation. Through the introduction of environmental values, technology and lifestyle change, the city hopes to eradicate the banes of modern city living - traffic jams, air pollution, noise pollution and inefficient public transport- an idea similar to the Garden City Movement where it is believed that a particular way of town planning can improve the lives of people (Hall, 2002). Likewise, the construction of Masdar has the power to enhance the way people live without resorting to environmentally - costly construction and operation. Masdar, therefore, redefines the needs of urban life in the new era of sustainability.

Very importantly, Masdar City has looked back at the indigenous ways that century old building traditions and technologies can be revised, updated and applied to today's construction. This is a sensible way of producing architecture for the modern era and suitably references the city to the local history and culture of its geography, thus contextualizing any city building to its local climate. We see in the case study of Masdar City, that the design team has reapplied traditional Arab city building principles to achieve passive cooling and other environmental benefits. Using local know-how to inform the urban development is an important resource in any sustainable development. This should be encouraged globally at various locations to create a built environment that relates to the local identity, but draws on construction intelligence developed over time.

6. Conclusion

Masdar City is an experimental urbanism, set to break many records and in this case, an important, meaningful and honorable one. If successful, as the first zero-carbon and zero-waste civilization on earth, it would set precedence as a sustainable urban model for future city design. This is particularly acute when issues of depleting resources are creating great problems in our planet such as global warming and its associated ill-effects that we are too familiar with. Coupled with the earth’s resources being stretched to support an ever increasing global population, this urban model is doubly significant if successful. If this project can really be carbon-free, it will imply that deserts, often not the most suitable of environments to sustain life, could effectively become feasible as lands viable for creating and supporting a sustainable community. The barren desert can therefore be reinstated to support human life at a significant level with sustainable merits deemed beneficial for the environment.

The design team uses advanced green technologies and reinvigorated traditional planning principles developed in a localized context over the centuries

to engineer a city with ambitions of a zero carbon-footprint. The results and effectiveness of these technologies is eagerly awaited when the city is completed and operating.

As seen within the publicity images and computer-generated fly-throughs the designers have created a seductive idyll of living in a city in the middle of the desert. Included within this paper are marketing images which makes one believe that this utopian view will one day become a reality. Interviews and scientific findings of inhabitants, and other stakeholders who eventually live, work and play in this city, conducted in the future would ascertain the real success of the construction of this city and its impact in urban planning and city building in the future.

Although there are criticisms about the projects, Masdar City is regarded as a ground-breaking project with an honorable cause. Since its high-profile launch at Cityscape Abu Dhabi in 2007, the tight building programme has resulted in this city taking shape very rapidly. The first phase of the project has been completed at the time of writing. The conception and construction of the city is viewed as an important resource of education and research for the present generation and future generations within Masdar City, Abu Dhabi, The UAE and the world at large. It is hoped that upon its proposed completion in 2016, Masdar City can meet its aspirations to become a world first carbon-neutral city.

Liken to The Titanic on its ill-fated journey to cross the Atlantic, Masdar City, currently under construction, is on a ground-breaking mission on its maiden voyage into unknown territory. It is with much anticipation the city can "arrive on the other side" and become a prime example of how urban development can take place sustainably in the future and be transformed from a theoretical mirage into a realistic possibility.

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