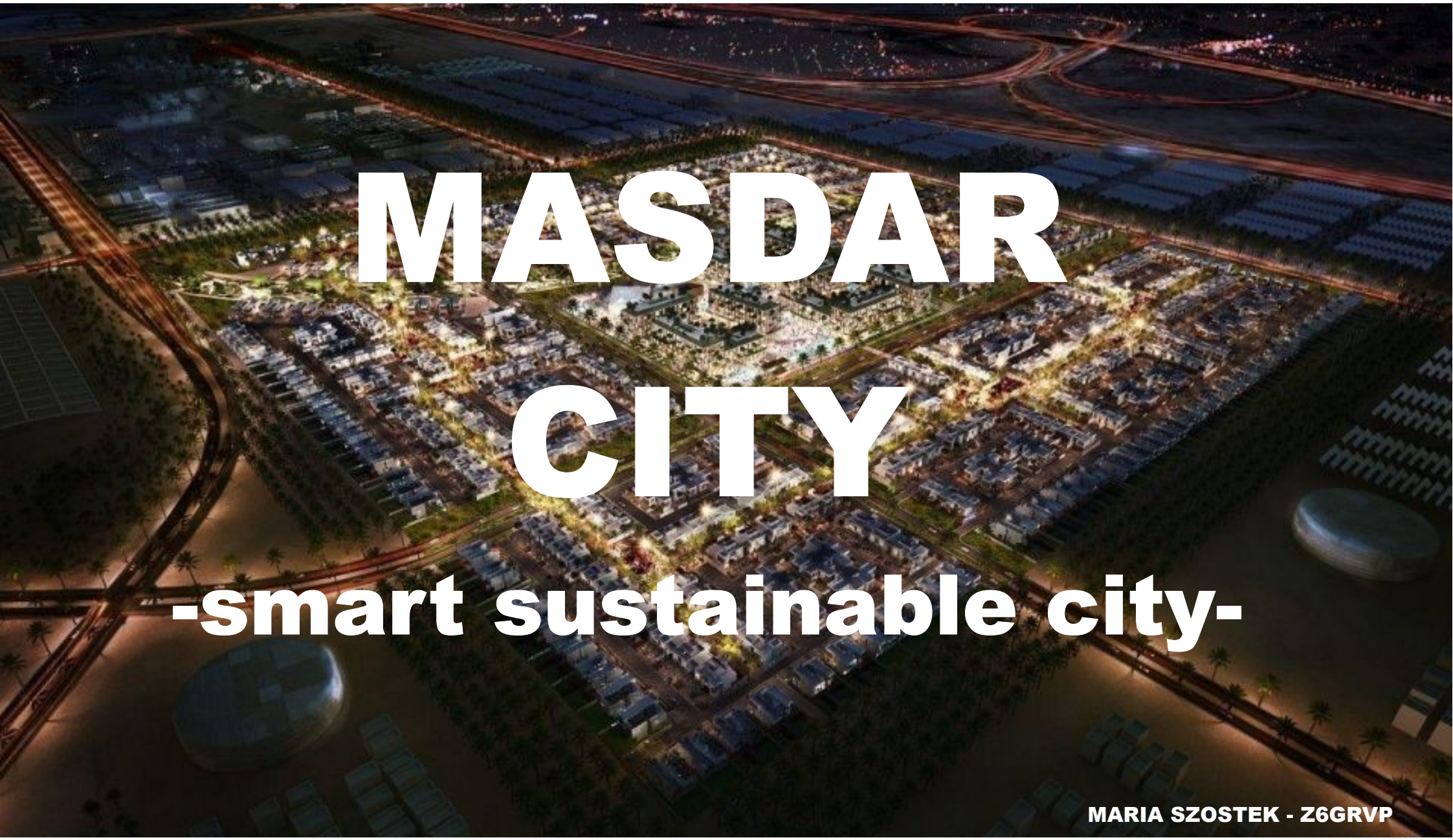

MASDAR
CITY
-smart sustainable city-
MARIA SZOSTEK - Z6GRVP

INDEX

ABSTRACT

This reasearch is about Masdar City as an example of smart sustainable city.

The main aim of the study was to analyze the functioning of the ecological city of the future, which is Masdar City in the United Arab Emirates, already treated today as a kind of global benchmark. Thus, the research object was not only a city, but especially solutions adopted in it. At the initial stage of research, I focused on the analysis of the city, its history, architecture, type of transport, and lifestyle.
The next stage of my work was to describe the technologies used in the Masdar City project. The methods of generating and transforming energy in the smart sustainable city in the United Arabian Emirates, were also analyzed.

In the last part of the research – conclusion – I cited several irrefutable facts, thanks to which questions about the future of the smart sustainable cities and their law of being, arise. I absolutely do not negate the experiment which is the Masdar City, I just want to draw attention, despite the generally prevailing admiration of a modern city, that this project is still struggling with many problems, which should act as a warning to similar experiments and encourage their authors to considerations about what can be improved in the cities of future which should serve not only to general admiration, but above all, to the comfortable life of people.

INTRODUCTION

Forecasts indicate a continuous increase in the number of people living in metropolises around the world, they also indicate the need for a completely different approach to the solution of contemporary and future problems of cities. In some countries interesting solutions have already appeared, and in the opinion of many authors, one of the most interesting examples of an ecological (sustainable) city is Masdar City in the United Arab Emirates. It is a kind of benchmark of numerous technological solutions. The concept of the smart city emerged more than a decade ago. Use of the newest technologies is an important topic in many countries, nowadays. Using technology to serve people and develop the city has been a goal for many years. Over time and technology development, cities are becoming more and more automated. Machines, robots, computers help people in many areas of life and, unfortunately, sometimes they even replace them. The main reason for the development of sustainable cities idea is the need to protect the environment, not only urban one, but understood much more widely, especially in the context of the necessary reduction of energy consumption, the use of renewable energy, as well as full management of many categories of waste, because currently the metropolises generate the largest amounts of various types of pollution. Cities are also the biggest consumer of energy, much bigger than industry and transport. An sustainable city is a city where you can observe balanced energy use, water management, waste management according to the latest available eco-innovations and what is important, use of renewable sources of energy. But what exactly is a smart sustainable city? To ensure that the sustainability aspect in smart cities is not overlooked, the ITU–T Focus Group on Smart Sustainable Cities has conceptualized the new term, based on an analysis of about a hundred different definitions. The following definition was agreed during the fifth meeting of the Focus Group on Smart Sustainable Cities held on 19–20 June 2014 in Genoa, Italy: *“A smart sustainable city is an innovative city that uses information and communication technologies and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects”.*The smart sustainable city is characterized by a large proportion of green areas, pro-ecological solutions, multimodal transport and widespread use of others intelligent IT solutions. It combines economic, social and ecological issues into one efficient system.

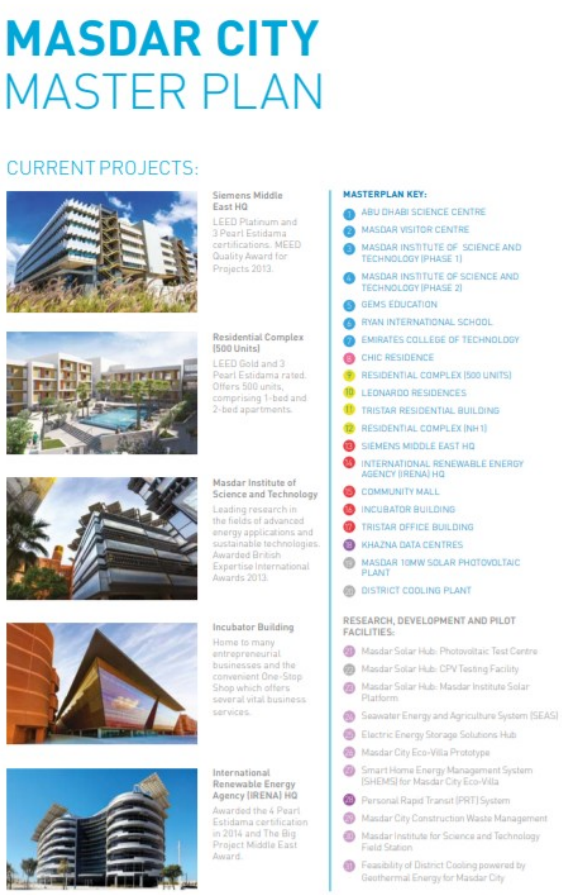
MASDAR CITY

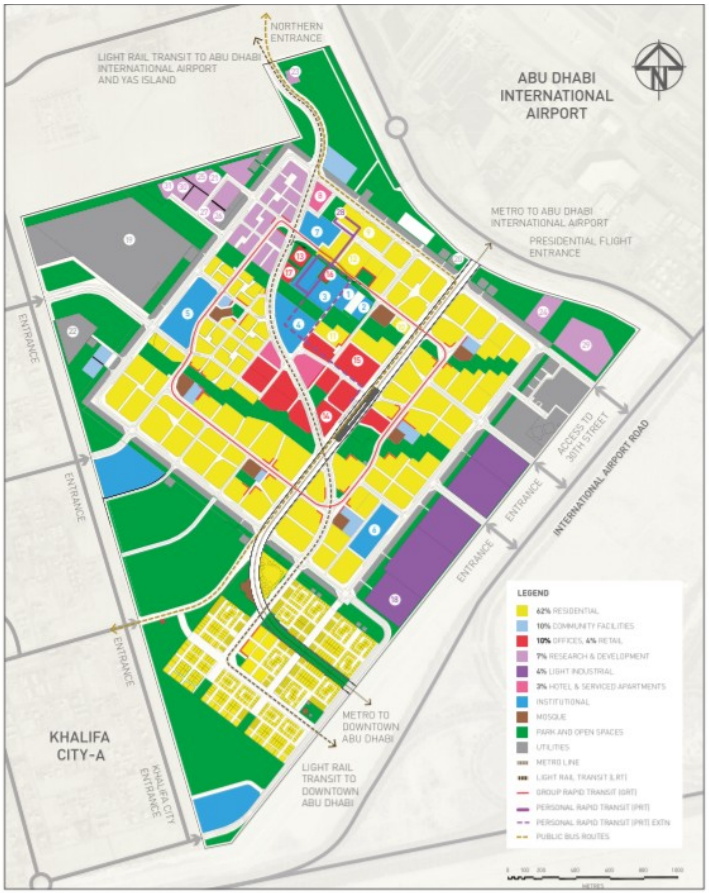
Masdar City, an eco-city presently being built in the United Arab Emirates which aspired to become the first zero-emission city in the world, non-generating waste and one hundred percent based on renewable sources of energy. The city was designed by the British architectonic company Foster and Partners and engineering and environmental consultancy Mott MacDonald. Its goal was to revolutionize thinking about cities and the created environment. However, there is a risk for the Masdar to be titled as the world's first green ghost town. A project of a completely zero-emission city, initiated in 2006 by the government of Abu Dhabi. Masdar City was planned to attract 1.5 thousand companies, 40 thousand employees commuting to work and also become home for around 50,000 residents. The city is actually a part of a larger program, called Masdar Iniciative, headed by Abu Dhabi Future Energy Company, being a subsidiary of Mubadala Development Company, the main investor of Masdar City. "Masdar" in Arabic means "source". This name is supposed to refer to the aspirations of the creators about making their modern city a global source of knowledge and innovation on sustainable urban development and smart planning. The project has already attracted interest from international companies such as Consensus Business Group, Credit Suisse or Siemens. They help the Emirates develop clean technology in Masdar. The city has also become the seat of the International Renewable Energy Agency (IRENA), which promotes the sustainable use of renewable energy on a global scale. Its quarters are located in a modern hexagonal building, which uses only 1/3 of the energy consumed in similar office buildings in Abu Dhabi, thanks to its insulation, natural lighting, high-performance elevators and solar water heating on the roof. This is just one example of Masdar's aspirations in pursuit of creating the most ecological building in the world. The city, built on six square kilometers of desert, 16 km from the capital of the United Arab Emirates, in accordance with the idea of sustainable development, acts as a laboratory for advanced eco-technologies, becoming a pioneer in the minimal impact of the city's space on the environment. Its aim is to encourage other metropolises to become energy-saving oriented.

LOCATION

Masdar City is located 16 kilometers from Abu Dhabi, beside Abu Dhabi International Airport. It is easily accessible from all the international airports of all major cities of UAE. It is 154 km from Sharjah Airport, 136 km from Dubai International Airport nearly 1 and half hour drive.

PLANNING AND DESIGN





The location of the city in the middle of a desert region and its maintaining high temperature was a huge challenge for creators of the city. The entire plan of the city is oriented along an optimal northwest-southeast axis to maximize shading—a result of comprehensive solar movement studies—and wind movement. The edges of the platform that the city is built a top has ‘crubmly edges’ to encourage wind vortexes and cooling. The important aspect of planning and designing was a reduce of energy required in cooling systems. Omitting the allegations of moving away from history and culture, the city’s master planners undoubtedly took inspiration from traditional Arabian city planning. The project was adapted to the desert climate. It is characterized by relatively low overall energy consumption. Traditional Arabian cities are compact and densely populated. Hence the city has a population density of 140 people/hectare and average height of buildings is maintained to 4-6 storeys.

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 ofthe 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 is 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." (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./I 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.

ARCHITECTURE

The truth is that the architectural landscape has changed quite radically. We aredoing some of our largest projects in the desert, for example, in extreme climaticconditions, and that suggests a certain kind of response. With Masdar we began bylooking at the regional vernacular — the 'architecture without architects' thatexisted historically — and then aimed to build for zero carbon and zero waste, withthe least amount of embodied energy. (Norman Foster)

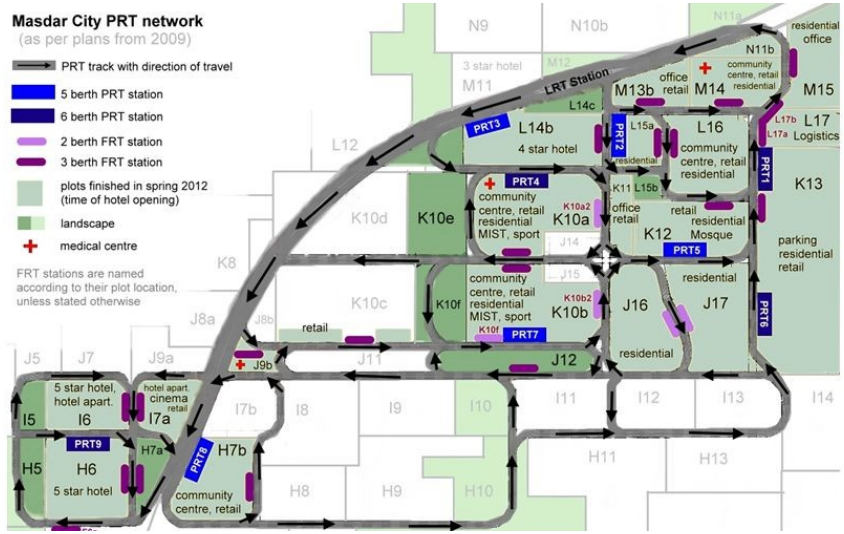
Architects while designing the city, drew from the knowledge and experience of traditional architecture. It helped them cope with the harsh climate of the country. Traditional features that we can observe in Masdar City are: narrow streets, natural shading, high density /low rise Living, public spaces, mixed use, walkable distances. The residential concept for the Masdar Institute focuses on the creation of lively energetic neighbourhoods. The university campus is conceptualized around a hierarchy of streets and squares that form the backdrop to an environment of integration, communication and co-operation; a place active day or night (Joss S., 2010). To conform to Middle Eastern standards of privacy, Mr. Foster came up with an undulating facade of concrete latticework based on the mashrabiya screens common in the region. The latticework blocks direct sunlight and screens interiors from view, while the curves make for angled views to the outside, so that apartment dwellers never look directly into the windows of facing buildings. (nytimes)

Apartments are accessed via a fully shaded, atrium space that exploits thermal mass and natural ventilation to provide free cooling – atrium roof lights allow diffuse daylight, blocking direct sunlight and providing additional roof area for PVs.

Acoustic separation ensures privacy and peaceful study. Window areas vary in response to daylight availability, and are positioned to wash walls and ceilings with daylight. Windows are protected by a contemporary reinterpretation of mashrabiya, a type of latticed projecting oriel window, constructed with sustainably developed, glass-reinforced concrete, coloured with sand to integrate with its desert context and minimize maintenance. The laboratories and residential accommodation are supported by a gymnasium, canteen, café, knowledge centre, majlis – or meeting place – and landscaped areas. Fresh air volumes reduced by over 40% through the use of active air management systems. Fully shaded windows minimize direct solar heat gain to reduce overall energy required for cooling (Ouroussoff N, 2010). Residential buildings are defined by the red sand-coloured, undulating glass reinforced concrete (GRC) screens that serve much the same role as traditional Arab mashrabiya screens. They provide shade from the sun, thus preventing solar gain on the building walls; they allow residents to look out at the street below while maintaining their privacy, and they also permit air to pass through to cool the balconies. Aside from the windows, the rest of the façade is again highly sealed and insulated, and wrapped in 90% recycled aluminum sheeting in the same rose-red colour as the GRC screens. The apartment units themselves have screen-shielded windows and windows located near the ceilings to maximize natural light, both from the outside and from the interior atrium, while maintaining privacy.

TRANSPORT

Due to the fact that Masdar City has a zero-emission policy, the use of cars in the city area is strictly prohibited. Public transport is acummulated underground,in the form of special public electric cars. The terrestrial space of the city has been designed taking into account only the needs of pedestrians and cyclists, that is why all institutions and services were located close enough to be able to reach them freely by bike or on foot.



"*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 effident 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 buming oils and car fuel, it is a terribly inefficient way of using fue."* (Evenden interview)

The city will be linked to Abu Dhabi City and the airport, as weil as other nearby communities with Light Rail Transit System (LRT) - 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. Underground cars seats up to six people and are fully automated and run on a recyclable lithium-cadmium battery, which can be charged while the vehicle is waiting at the station. There is no driver needed because the only information that those computer controlled vehicles need is the destination point of travel, so that the machine can led you to the place without stopping on the way at any other stops. The cars mechanically run on repelling magnetic forces in a multi-level, barrier-free environment. The journeys will be planned and time-tabled sophisticatedly to prevent traffic jams, eradieating stresses of eity trave. These pod cars journeys will last a maximum of 7 minutes between any of the 83 stations at any point within the city. Commuters and visitors are forced to leave their cars in underground garages and use the urban rapid individual transport. The city plans to have between 2.5-3 thousand such devices with the infrastructure of 83 stations. 3000 pod cars will make up to 135,000 trips per day The resignation from cars has a huge contribution to Masdar's being rhe most ecological city in the World. Not only it reduces greenhouse gas emissions and toxins, but also helps to reduce the perceived temperature in the city.

LIFE IN MASDAR CITY

Masdar City seems to be perfect heaven on earth. Ecological city in which technology serves human beings. But is it so ideal? L. Snyder pointed out that regulations related to emission control and measurements of energy consumption may result in Masdar residents feeling of restriction and living under constant observation, as in a totalitarian society, due to the ubiquitous monitoring devices. Comparing Masdar policy to totalitarian system is quite bold, but in a way it shows that the excess of control and restrictions imposed on people can cause a sense of overwhelming and discouragement to the city.

Controlling the lifestyle in Masdar in order to achieve its goals of an unemotional city can actually influence the potential residents of resigning from the desire to live in the "city of the future". As Snyder points out, restrictions related to the ban on the use of own car in the city are also limited by the individual freedom of movement, because they impose a specific way of life, and yet walking and cycling in a desert climate may not be the best important. Transport PRT has a limited number of stops, and in addition, the cars are moving quite slowly. The biggest oversight of their creators may be the fact that, on average, the Emiradz family consists of 7.28 people, and the vehicles were designed for 6 passengers. The underground transport system can also be troublesome when moving heavy items and supplying stores. The question arises whether the city is focused on people or only on modern technologies?

MASDAR INSTITUTE OF SCIENCE AND TECHNOLOGY

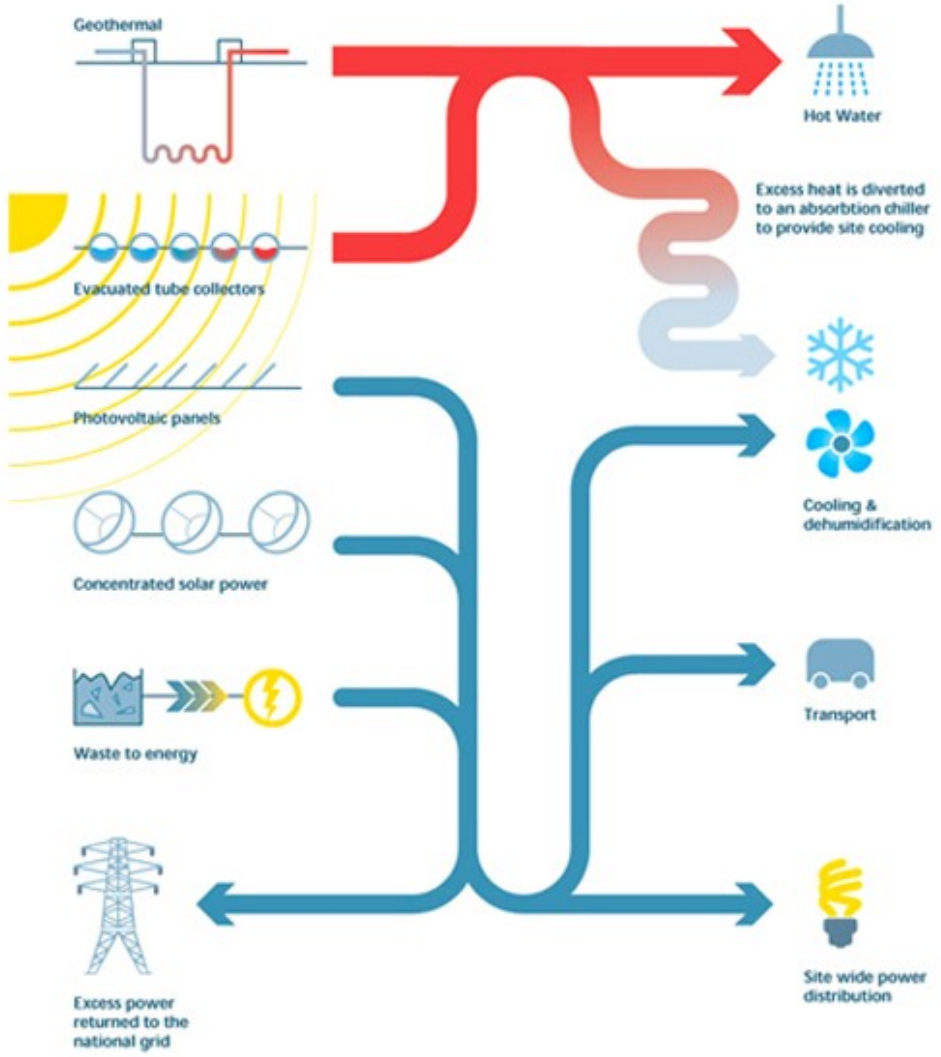
Masdar Institute of Science and Technology is an independent non-profit institution, a center for highly advanced research, mainly focused on renewable energy and other sustainable technology. The Masdar Institute of Science and Technology was founded with the support and cooperation one of the world's most prestigious universities, the Massachusetts Institute of Technology (MIT). Its is university which mainly deal with research focused on issues relevant to the development of the United Arab Emirates and the Abu Dhabi region. In close proximity to the capital of this country such a interesting scientific unit was created. Its aim is also to support the economic diversification of the Emirates, educating highly qualified personnel to transform the knowledge-based economy up to the vision of 2030. The Institute's employees focus on complex problems of contemporary reality and the future that require a broad, interdisciplinary approach. The Institute is therefore a source of innovation (eco-innovation).

The main areas of searching for new technological solutions are:
smart buildings and smart grids; green supply chain: green database provider; clean transport infrastructure, energy storage technologies, integration of transport systems; information technologies, sustainable management systems, intelligent communal solutions; energy-efficient lighting and heat energy, geothermal cooling.

ENERGY MANAGEMENT

Masdar as a enerfy-saving oriented city minimizes energy consumption by deploying the best commercially available international energy-efficient techniques such as insulation, low-energy lighting specifications, the percentage of glazing (i.e., windows), optimizing natural light, and installing smart appliances, smart building management systems. Onother step was choosing appropriate techniques to generate the required energy. Due to a large financial outlay and desire to achieve the goal many different innovative techniques were used to get the maximum energy.

Some of the techniques are:



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, interview)

One of the Masdar City aim is to minimise water waste and maximise the efficiency of treatment and production techniques. The city planners say that 80% of water used in city would be recycled. For the next years the goal is to gradually reduce the domestic water consumption to the target potable water consumption of 105 litres per person per day. Water-use reduction technologies include high-efficiency appliances, low-flow showers, highly efficient laundry systems, a water tariff that promotes water efficiency, incentives, real-time monitoring, smart water metres that inform consumers of their consumption, reducing leakage ultimately to 1%, treated wastewater recycling, and high-efficiency irrigation and low- water use landscaping, particularly through use of indigenous desert flora. The current wastewater system combines greywater and blackwater for processing and treatment at the city"s membrane bioreactor (MBR) plant. Waste water treatment at Masdar City is being provided by a membrane bioreactor (MBR) with a capacity of 1,500 cubic metres per day. The MBR process involves a suspended, growth-activated sludge system that uses microporous membranes for solid/liquid separation in lieu of secondary clarifiers. After irrigation of crops water goes down through the top 2 or 3 feet layers of soil and then meets plants' requirements and underground water collection system recovers whatever amount of water is left. The treated sewage effluent produced at the MBR will be used for landscaping. The biosolids resulting from the wastewater treatment can be reused for compositing and in any future waste-to-energy plant. (Masdar Introduction, 2010)

SOLAR POWER

The Masdar City Solar Photovoltaic Plant is the largest of its kind in the Middle East.The facility produces about 17,500 megawatt-hours of clean electricity annually and offsets 15,000 tonnes of carbon emissions per year. The plant consists of 87,780 multicrystalline and thin-film modules supplied by Suntech and First Solar. Yhe plant occupies a 22-hectare site at the outer boundary of Masdar City. Important aspect was selecting the right technologies for Abu Dhabi’s climate. For selection of right type of panels tests were carried out. International PV Competition was organized in September 2008. The results from the test field help guide Masdar City in selecting the best PV modules for both roof and ground placement.

Inaugurated in May 2009, the farm provides clean energy to the Masdar Institute campus and Masdar"s temporary on-site offices, as well as some of the ongoing Masdar City construction activities.

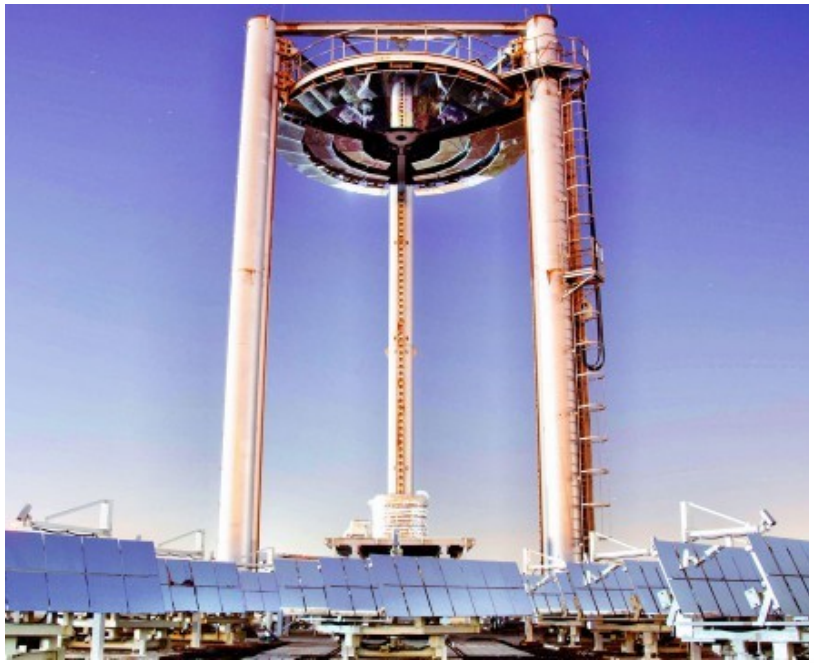
In Masdar City we can also find another manners to collect solar power, such as:

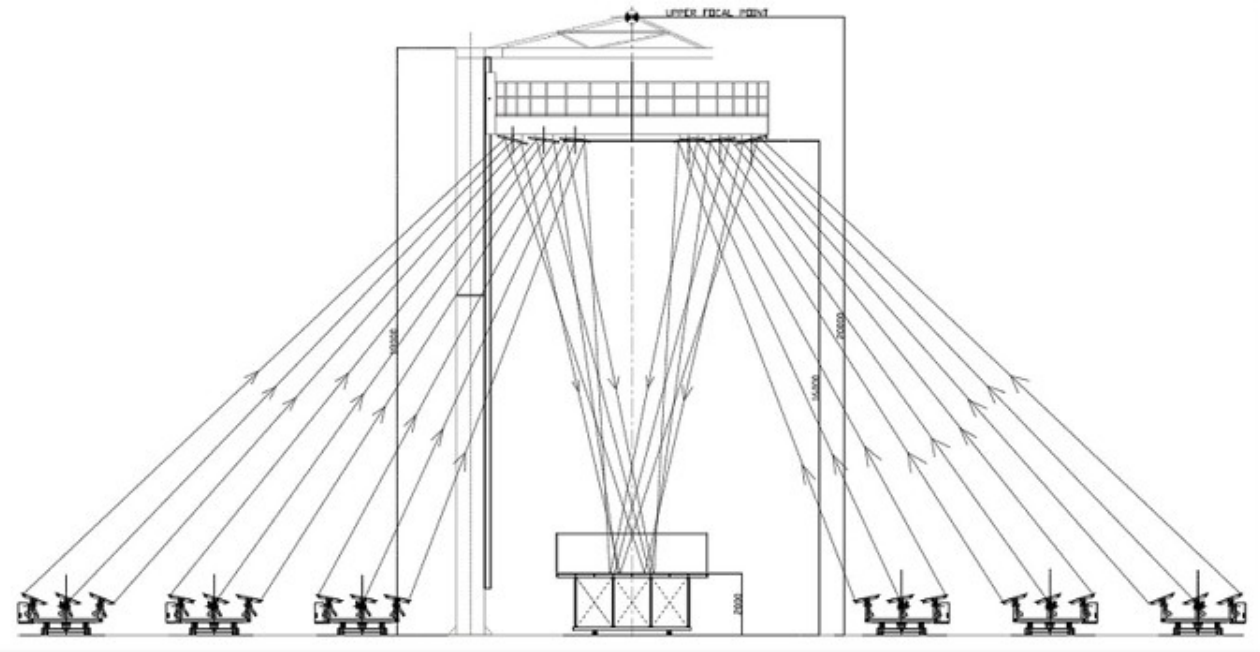
Concentrated Solar Power (CSP) it is a systems wchich use mirrors or lenses to focus a large area of sunlight, or solar thermal energy, onto a small area. When the concentrated light is converted to heat, it drives a heat engine connected to an electrical power generator. The result is electricity. Masdar uses different types of concentrated solar power systems.

Shams 1 located in western Abu Dhabi is a parabolic trough system, a cluster of solar thermal collectors in the form of parabolic mirrors, with a central tube to concentrate the heat from direct solar irradiation. The heat in turn produces steam to drive a conventional turbine that ultimately generates electricity. It occupies 2.5 square kilometres and has a capacity of 100 megawatts. The solar field has 768 parabolic trough collectors.

Masdar's Gemasolar and Valle 1 & 2 facilities use a central tower that consists of an array of reflectors (heliostats). They concentrate sunlight on a central receiver on the tower. The receiver contains a fluid, often seawater, that is heated to more than 500 degrees Celsius and then used as a heat source for power generation.

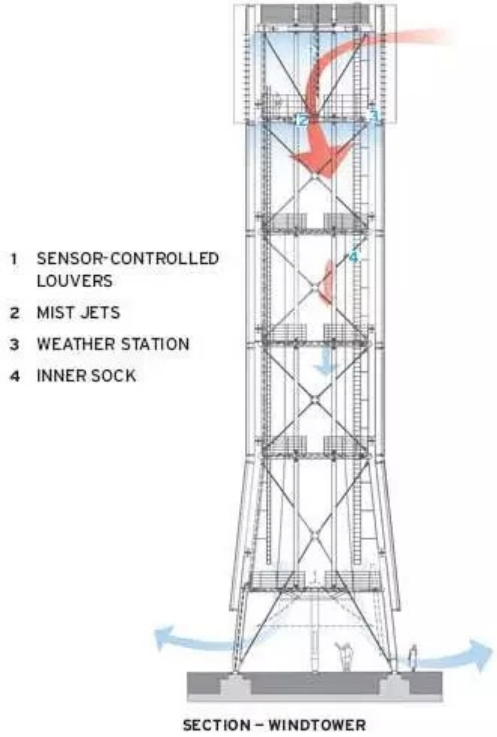
The other way Mastar City can collect solar energy is the merit of the only such tower in the world - the Beam Down Optical Tower. TheBeam Down Project is a joint pilot project of the Masdar Institute, Japan"s Cosmo Oil Company and the Tokyo Institute of Technology. The special construction of the mirrors is supposed to reflect sunlight towards the building. Solar energy is also intended for desalination of seawater, as well as for heating water and generating water vapor. The surplus energy Masdar produces sends to Abu Dhabi. The project includes the construction of a IOMW 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 leamt that the solar farm is currently producing excess energy where this is returned to the national grid.





WIND MANAGEMENT

Windower rising 45m above the podium, this modern interpretation of one of the region's most iconic traditional architectural features will be a landmark for the Masdar Institute neighbourhood. The tower's height means it can capture upper-level winds and direct them to the open-air public square at its base. Sensors at the top of the steel structure will operate high-level louvers to open in the direction of prevailing winds and to close in other directions to divert wind down the tower. A PTFE membrane will carry the wind downward, while mist generators at the top will add additional cooling to the air. PTFE is the scientifi c name for the well-known non-stick brand Tefl on. Combinations of evaporative cooling and air movement techniques help to moderate perceived air temperatures, thereby improving personal comfort. Masdar Institute will use the tower as a platform for their scientifi c instruments. This includes weather measuring equipment and air quality testing tools.



SECTION – WINDTOWER

MATERIAL RECYCLING CENTRE

Masdar City is working to minimise waste during the construction process by seeking to reuse and recycle up to 96% of construction waste such as steel, concrete and timber generated during building. In order to achieve this, nearly all Masdar City construction waste is brought by contractors to the onsite Material Recycling Centre (MRC) for separation and processing. The 12-hectare site is divided into areas for concrete, wood, metal and other materials, which then are made available for use by other contractors working on site. Wood is segregated and stockpiled for reuse in building the city or processing in a wood chipper. Steel, other metals and plastics are collected and sent offsite for recycling. Concrete waste is ground down using a crusher for reuse in construction. This material is particularly handy as infi ll, given the loose soil conditions at Masdar City. In addition, excavated sand is being stockpiled (rather than trucked away as is common on UAE construction sites) for reuse as general backfi ll. Other materials such as gypsum board and damaged glass reinforced concrete panels are being tested to see whether they can be recycled. Waste that cannot be recycled may be used as fuel in a future waste-to-energy plant. Diverting around 300,000 tonnes of solid waste from landfill each year, it will contribute to Sharjah's effort to reach "zero waste-to-landfill" target by 2020 and the UAE to deliver its 2021 goal of diverting 75% of solid waste from landfills.

The facility will incinerate around 37.5 tonnes of municipal solid waste per hour to create energy and will be located adjacent to Bee’ah’s existing Material Recovery Facility in Sharjah, where the emirate’s waste is collected, sorted, recycled and, where necessary, sent to landfills. The incineration process converts the waste into produced heat which is then used to drive an electrical turbine. The net electrical power produced will be around 27 MW which will be supplied to the Sharjah electricity grid. The flue gas of the waste incineration will be treated before being released into the atmosphere. The by-products of the waste incineration such as bottom ash are treated as well, temporarily stored at site and later collected by Bee'ah.

CONCLUSION

The discussed city unquestionably sets new standards in sustainable development and creates new trends in the use of ICT in urban space. It is more than just a modern city with hi-tech infrastructure. Masdar City constitute a model of the future development of urban centers, from which some inspirations are already derived. For this reason, in a situation where the Masdar solutions aspire to become the model ones, it is so important to critically analyze them, if only to indicate which ones should be abandoned and which ones are worth developing. There is undoubtedly a huge potential in the evolution of cities in a smart city concept The technologies - ubiquitous wireless networks, sensors and devices that collect data, self-driving cars, intelligent screens, cameras and other devices blending into the urban fabric - transform urban reality into the form of a smart city of the future. Despite being ’smart’,Masdar City is not ideal. Well-tended gardens, glass futuristic buildings, ubiquitous technologies that increase the quality of life of residents, impeccable air emphasize urban luxury - a clean, comfortable space with imperceptible poverty. This is the reason why this experiment can become a more attractive place to live for the rich than the symbol of the "urban life’s new order of organization". Orientation on new technologies and urban experiments may confirm the erroneous belief that all urban space can be reduced to an algorithm managed by computers. Digital technology appears to them, as Barber put it, as "a source of utopian optimism about its transformative power" and the belief that it is able to save us from all problems. Also, we can not forget that in the case of Masdar City, it is also a source of money in which project powerful corporations are involved. So far, its creators, by testing ICT technologies and city management concepts in real spaces and living organisms, have shown that even building from scratch, fully thought out space, based on the latest solutions and intelligent technologies, is not free of mistakes and oversights.

The example of Masdar City shows that technologies (which themselves can fail and generate errors) can not be the only determinant of the city's "intelligence". It is also a matter of intelligent management, which should take into account the specificity of a given center, its culture and, above all, the needs of residents. The population of the "city of the future" struggling with the problem at this moment is not a paradise on earth for people. So far, the experiment has encouraged a little over 300 people to settle down - most of them are graduates Institute of Science and Technology, who have been paid tuition and accommodation.

Masdar City as an example of attempt to use great technologies and the most modern inventions, in some way warns against excessive focus on being number one in the innovation department, forgetting or downplaying the needs of those who are supposed to settle this city. On the other hand, we can not forget about how many good things the construction of Masdar City brought. New inventions, international cooperation, and what is very important, the dissemination of smart cities is one of many advantages of this experiment. We must hope that over the years, the concept of smart sustainable cities will evolve and give us better and more convenient solutions.

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