Towards Sustainable Development in the Middle East: A Comprehensive Analysis and Case Study of Masdar City

By: Hendren Hamid Abdulrahman (Architect)

Architecture Department, College of Engineering, University of Sulaimani

Sulaymaniyah, Kurdistan Region of Iraq

https://orcid.org/0000-0002-8238-3193

Handren.Architect@gmail.com , Hendren.Abdulrahman@univsul.edu.iq

Kurdistan Engineering Union Member, Sulaymaniyah, Card NO : 9525

12/2023

Abstract:

This paper delves into the challenges and opportunities for sustainable development in the Middle East, a region characterized by rapid economic growth and environmental concerns. Focusing on the pillars of sustainability—environment, community, and economy—the paper discusses key issues such as global warming, water scarcity, energy consumption, and financial crises. It further examines the major solutions proposed to address these challenges, emphasizing recycling, sustainable development regulations, renewable energy, and water efficiency.

The paper critically evaluates Masdar City, a pioneering sustainable development project in Abu Dhabi, United Arab Emirates. The city's design, integration of traditional and modern architecture, use of sustainable materials, and implementation of renewable energy and efficiency solutions are analyzed. The discussion includes insights into the city's sustainable operating practices and the role of technology in monitoring and controlling energy consumption.

Drawing conclusions from the Masdar City case study, the paper underscores the importance of flexibility in design, a harmonious blend of traditional and modern strategies, and the need for collaboration between designers and stakeholders. It also acknowledges the challenges of implementing such projects on a global scale, emphasizing the necessity for more successful green initiatives to mitigate environmental impacts and foster sustainable practices in the Middle East.

Keywords: sustainable development, Middle East, Masdar City, environmental challenges, sustainable solutions, green architecture, renewable energy, water efficiency, recycling, case study.

Introduction

Middle East: a Sustainable Developing Region

An ecosystem represents the intricate harmony between society and its environment, where a symbiotic relationship with the economy plays a pivotal role. Acknowledging the interconnectedness of these pillars is paramount for achieving sustainability, as demonstrated by the Middle East. Despite being a powerhouse of development, the region grapples with the environmental consequences of its economic boom, particularly evident in the proliferation of skyscrapers, malls, and towers.

Challenges of Development:

The Middle East, heralded as one of the world's most developed regions, has experienced an unprecedented surge in construction fueled by its abundant oil reserves. However, this economic prosperity comes at a cost. The construction of modern edifices, while symbolizing progress, has led to excessive resource consumption, environmental pollution, and a surge in greenhouse gas emissions. Notably, buildings account for nearly 50% of the developed world's fossil fuel consumption, contributing significantly to global climate change (Roaf, Crichton, Nicol 2009, 4).

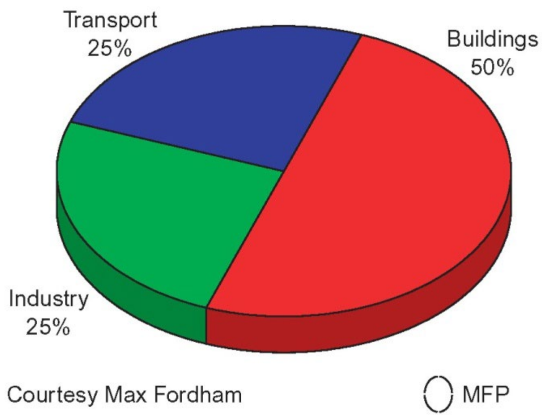


Fig 1: Fossil fuel use in developed economies of different sectors and their emissions

(Copyrights: Max Fordham and Partners).

The Call for Sustainability:

To address these challenges, there is an imperative need to shift towards sustainable development practices. The recognition that the pillars of society, environment, and economy are interdependent underscores the urgency of adopting a holistic approach. Sustainable development, defined as meeting present needs without compromising the ability of future generations to meet their own needs, becomes a guiding principle (WCED 1987, chap. 2). This definition transcends generational considerations, extending its scope to encompass the unity of countries and peoples worldwide. It underscores the interconnectedness of nations and individuals in a shared responsibility to address global challenges and minimize risks.

Environmental Impact of Modern Buildings:

The construction boom in the Middle East has inadvertently led to environmental degradation. Modern structures, while showcasing architectural prowess, tend to be resource-intensive, resulting in pollution and excessive waste generation. Furthermore, their substantial contribution to fossil fuel consumption exacerbates the global climate crisis. The pressing need for a paradigm shift towards sustainable architecture is evident.

Path to Sustainability:

Recognizing the gravity of the situation, the Middle East is taking strides towards a greener future. Countries in the region are setting ambitious green goals and implementing sustainable projects. Visionaries like Hassan Fathy advocate for solutions that harmonize industrial progress with the demands of nature and society. Roaf emphasizes the adaptation and mitigation of buildings to climate change, urging a reduction in greenhouse gas footprints (Steele and Fathy 1997, 11-12; Roaf, Fuentes, Thomas 2007, 1-5).

Smart Architectural Design for a Sustainable Future:

Smart architectural design is pivotal in realizing sustainable development goals. The integration of sustainable techniques, solutions, and strategies is essential for constructing buildings that:

- Consume minimal energy.
- Preferably generate their own energy.
- Conserve water resources.
- Minimize waste production.
- Provide a comfortable living environment.
- Remain habitable and safe, even in the face of the direst predictions of climate change.

This proactive approach to architecture aligns with the broader ethos of sustainable development, ensuring that the built environment serves as a responsible steward of natural resources while meeting the needs of current and future generations.

Sustainable development is a global imperative that transcends individual nations and calls for collective responsibility. The Middle East's commitment to green goals and the implementation of sustainable projects reflects a regional dedication to building a better future. The integration of smart architectural design practices further cements the region's commitment to minimizing environmental impact throughout the entire life cycle of buildings.

Adopting Green Standards:

In contemporary times, numerous methodologies exist for assessing the environmental impact of buildings, crucial for evaluating their energy efficiency and carbon emissions across the phases of design, construction, and operation. Among these, Leadership in Energy and Environmental Design (LEED) stands out as a prominent environmental rating system, evaluating projects based on criteria including site sustainability, water efficiency, energy and atmosphere, material and resources, indoor environmental quality, and innovation (Bauer, Mösle, and Schwarz 2010).

LEED, having garnered recognition through its application in numerous buildings across the Middle East, holds a preeminent position compared to other rating systems like BREEAM. Its widespread adoption underscores its effectiveness in promoting environmentally conscious practices within the region.

Furthermore, the Middle-East Centre for Sustainable Development (MECSD) has been established with the specific aim of introducing sustainable standards across diverse development projects. Aligned with LEED guidelines, MECSD focuses on enhancing environmental performance and efficiency, contributing significantly to the region's commitment to sustainable development (MECSD 2013).

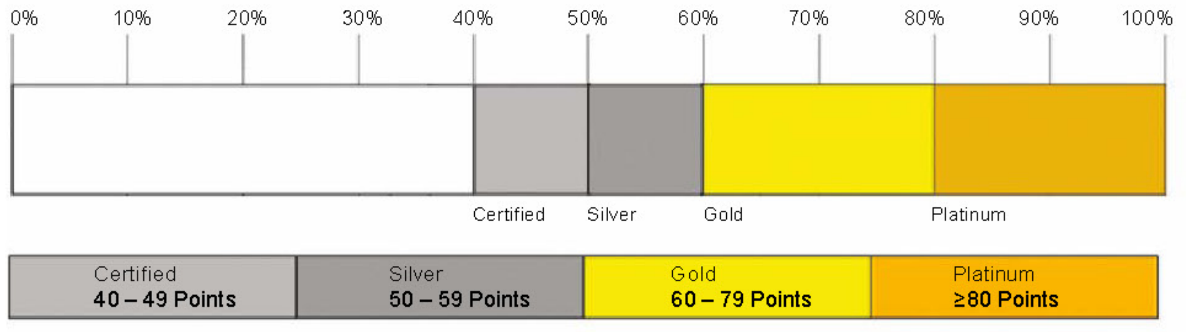


Fig 2: Evaluations of Leadership in Energy and

Environmental Design (LEED)

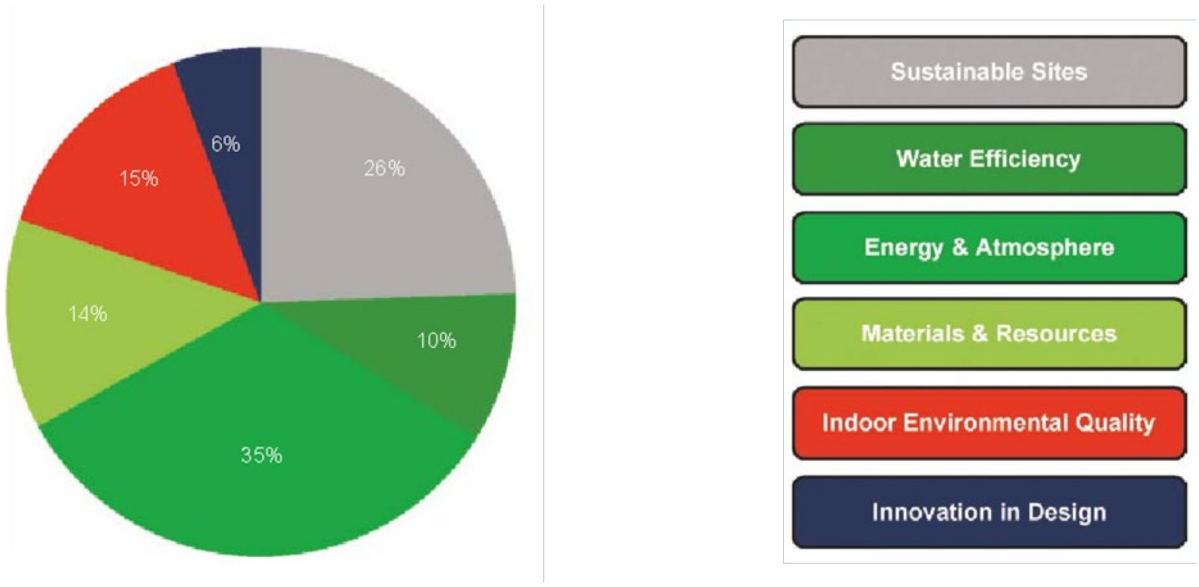


Fig 3: weight and structure of different sectors of LEED environmental assessment system

Key Issues in the Region:

1. Global Warming

The Middle East, situated in a hot and arid climate, faces challenges in building environmentally friendly structures that are both green and comfortable, especially considering the projections of global temperature increases. According to Intergovernmental Panel on Climate Change (IPCC) the Forth Assessment Report (AR4) in 2007, the world's temperature possibly might increase between 1.1 ° C and 6.4 ° C by the end of the century (Roaf, Crichton, Nicol 2009, 32)

2. Fresh Water Scarcity

Despite having only 1% of the world's fresh water for 5% of its population, the region grapples with declining fresh water levels, a consequence of global warming impacting rainfall and snowmelt (EIA 2011, 171; The World Bank 2012, 154-157).

3. Energy Consumption

The region, a major oil provider, provide the world with 30% of its need of oil, consumes a substantial portion of the world's energy, almost 5% of the world's energy, predominantly sourced from oil (EIA 2011, 157-229).

4. Greenhouse Gases Emissions

Reliance on fossil fuels has elevated the region's carbon dioxide emissions to approximately 5% of the world's total (EIA 2011, 167).

5. Financial Crisis

Despite economic prosperity from oil, the region faces a looming financial crisis if it fails to address the environmental impacts of oil extraction and consumption. Recent research suggests that the global depletion of fossil fuels, often colloquially referred to as "black gold," could potentially occur by the year 2100. This forecast, signaling a finite timeline for our reliance on these non-renewable resources, underscores the pressing need for a rapid and comprehensive transition to sustainable energy alternatives (Roaf, Fuentes, Thomas 2007, 4).

6. Material Shortage

The vast desert landscape has resulted in a shortage of natural materials, necessitating increased reliance on imports.

7. Sandstorms

Desertification and a lack of forested areas contribute to an increase in the frequency of sandstorms, impacting visibility, health, and infrastructure (Hartman 2010, 24-33; Bullis 2009, 56-63; Yassine, Elgendy 2011).

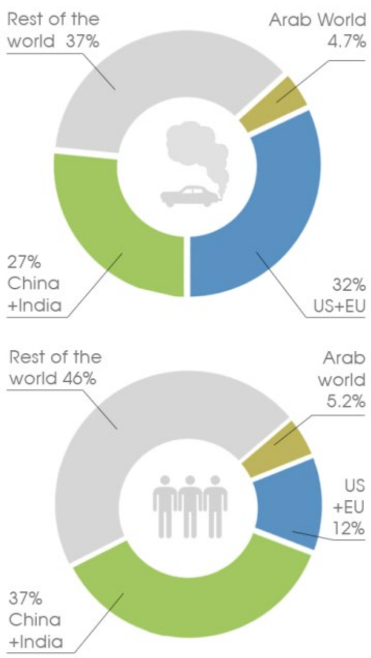


Fig 4: Total carbon dioxide ratios (Top) and population (bottom). (Copyrights: Carboun)

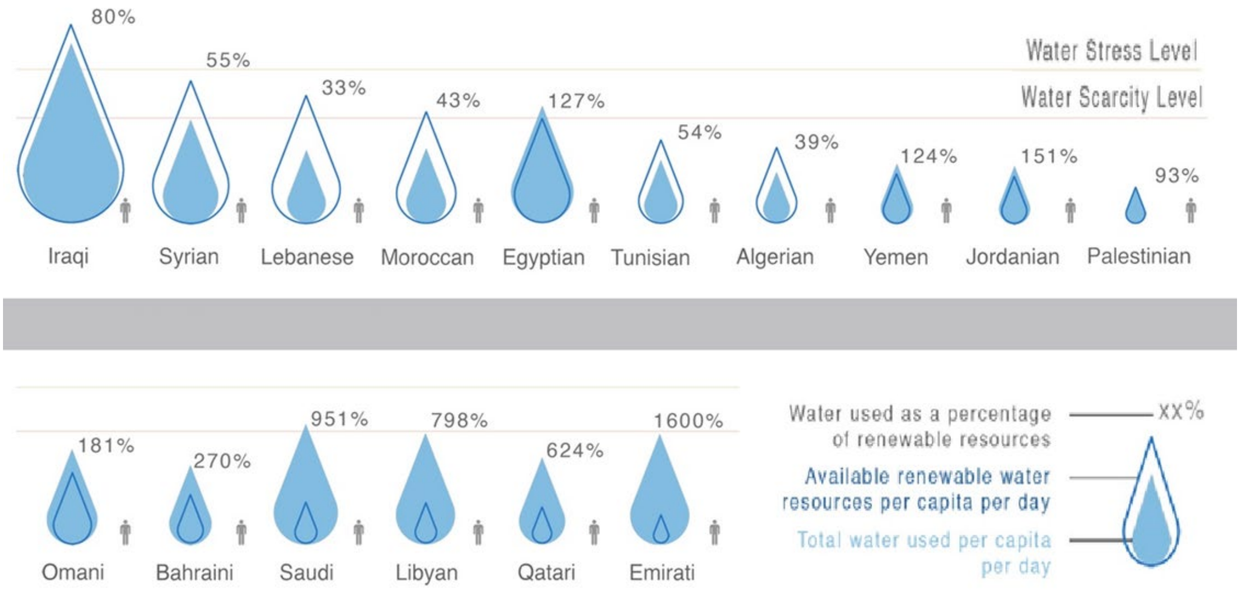


Fig 5: Total water consumption of different countries and percentage of renewable sources

(Prepared by: Karim Elgendy for Carboun)

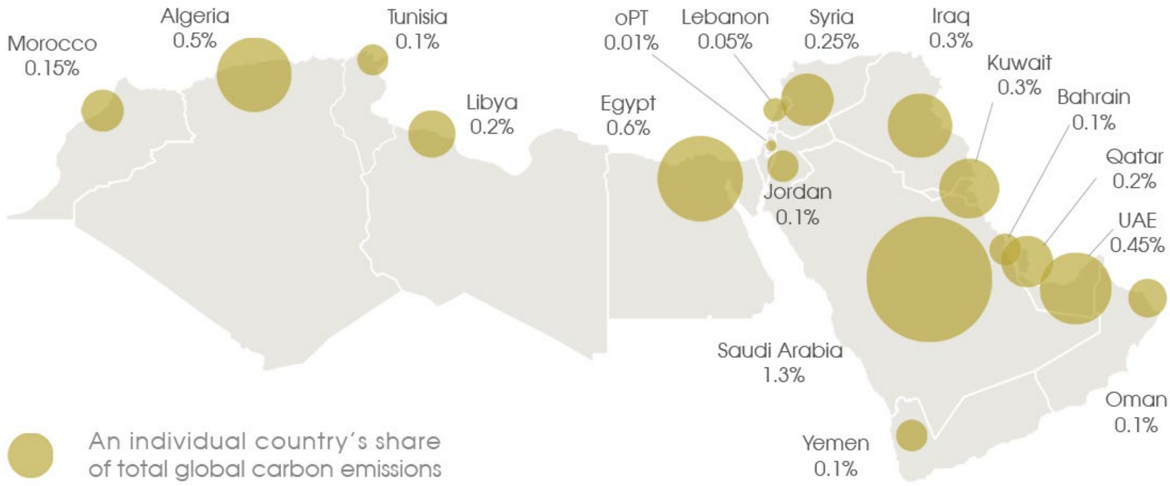


Fig 6: Individual share of total global carbon emissions of Middle East and North Africa countries

(Copyrights: Carboun)

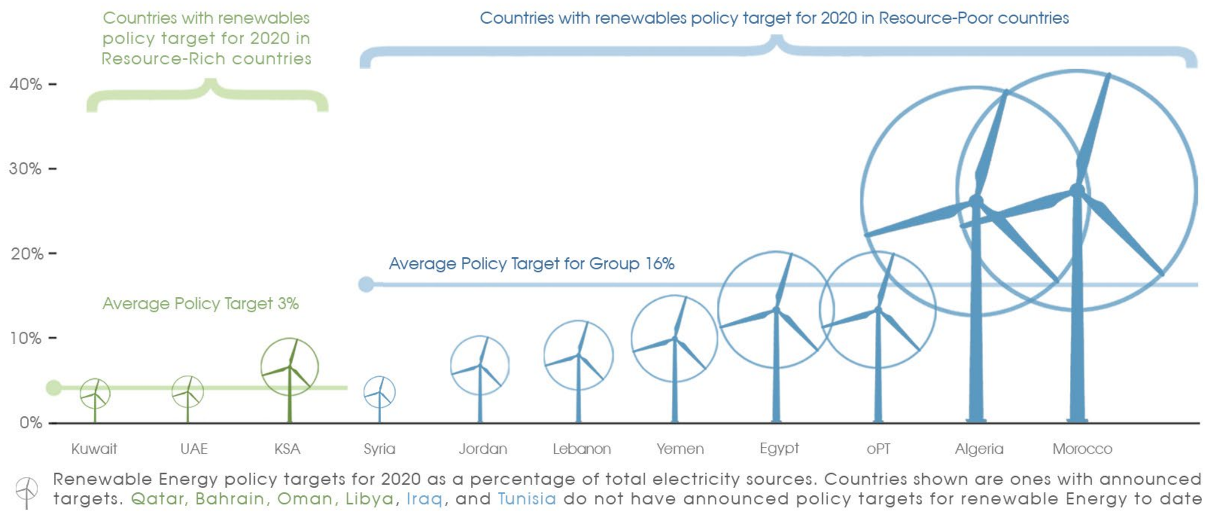


Fig 7: Percentages of renewable energy targets for 2020 of individual countries

(Copyrights: carboun)

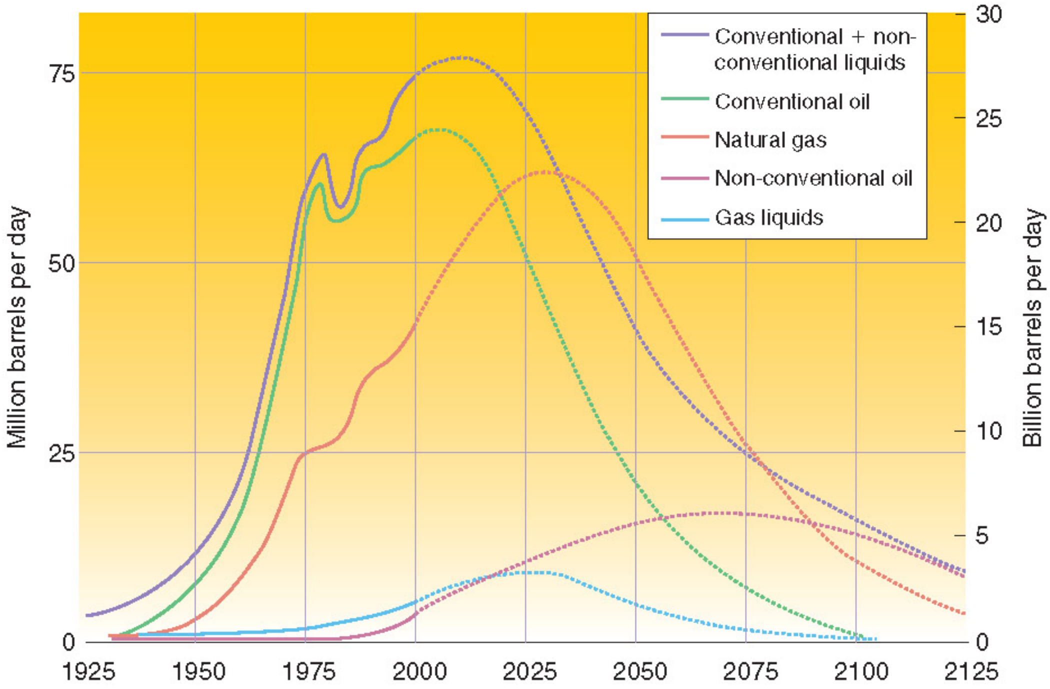


Fig 8: Graph shows different fossil fuel consumptions and predictions on when fossil fuels might run out

Sustainable Solutions:

1. Recycling: Implementing robust recycling initiatives to reduce waste.
2. Sustainable Development and Regulations: Enforcing sustainable building practices through updated regulations.
3. Renewable Energy Generation: Embracing renewable energy sources to decrease dependence on fossil fuels.
4. Greenhouse Gas Reduction: Implementing measures to reduce greenhouse gas emissions and improve air quality.
5. Water Efficiency: Implementing water-efficient practices to combat fresh water scarcity.
6. Durability and Sustainable Performance: Emphasizing durable and environmentally sustainable building practices.
7. Green Transport Systems: Investing in eco-friendly transportation options.
8. Green Economy: Promoting a sustainable and environmentally conscious economy.
9. Food Production: Implementing sustainable practices in food production.

Case Study: Masdar Development

- **Location:** Abu Dhabi, United Arab Emirates
- **Architecture Firm:** Foster + Partners
- **Client**: Masdar-Abu Dhabi Future Energy Company
- **Climate:** Hot and Humid Climate
- **Area:** 6 000 000 m²
- **Awards**
    - AJ100 Sustainability Initiative of the Year 2008
    - Cityscape Abu Dhabi - Best Sustainable Development
    - Cityscape Real Estate Awards – Best Environmental Real Estate Project
    - Condé Nast Traveler Innovation & Design Award (Sustainability)
    - FT ArcelorMittal Boldness in Business Awards
    - Global Renewable Energy Awards – Sustainable City of the Year

Fig 9: Masdar development master plan.

Highlighted part is under construction while the rest of it will be constructed in the future.

(By Foster+Partners)

Masdar City in Abu Dhabi stands as a testament to sustainable urban development. Designed with the principles of zero waste, zero carbon, and solar-powered energy, Masdar City seamlessly integrates traditional architectural techniques with cutting-edge technology. The city's commitment to sustainable practices is evident in its use of eco-friendly materials, water-efficient systems, renewable energy practices, and smart operating systems, reflecting a holistic approach to sustainability.

The city comprises six major buildings, including Siemens' Middle East Headquarters designed by Sheppard Robson, aiming for a LEED Platinum rating certificate, and Adrian Smith + Gordon Gill's headquarters—a structure generating more energy than it consumes. Additionally, Masdar City accommodates institutes, a library, and apartments for 7,000 residents and 12,000 visitors (Foster 2013) and (Vidal 2011).

Kaled Awad, the director of the Masdar project, emphasized, "The quality of air will be better than any other street in the Gulf and in the world, and that alone will bring you safety, health, and happiness" (Heap 2010).

Site Plan and Design:

The integration of traditional architecture and modernity is evident in Masdar City's design. Foster + Partners employed traditional techniques alongside modern technological solutions to enhance the eco-efficiency and performance of the buildings.

Traditional techniques, such as the high walls surrounding the city, compact building patterns, and winding narrow streets, contribute to the city's efficiency, protecting it from sandstorms and facilitating passive cooling. Solar power plants situated outside the city and roof-mounted photovoltaics provide clean and renewable electricity. Public buildings and laboratories feature sensitive and self-adjustable facades to climate change, incorporating materials with minimal embedded energy.

Masdar City, designed to be a car-free zone, promotes pedestrian-friendly spaces and utilizes driverless electric cars controlled by a "green policeman." The city is connected to Abu Dhabi by a light railway.

Buildings are strategically oriented with close proximity to each other, providing shade to streets and nearby facades. Mashrabiya screens, made from glass-reinforced concrete and colored with local sand, are applied to the vertical facades of residential buildings, offering shade while allowing natural ventilation with the assistance of wind towers and courtyards (Hartman 2010, 24-33), (Bullis 2009, 56-63), and (Yassine and Elgendy 2011).

Fig 10: Overall sustainability strategies of Masdar city's green design

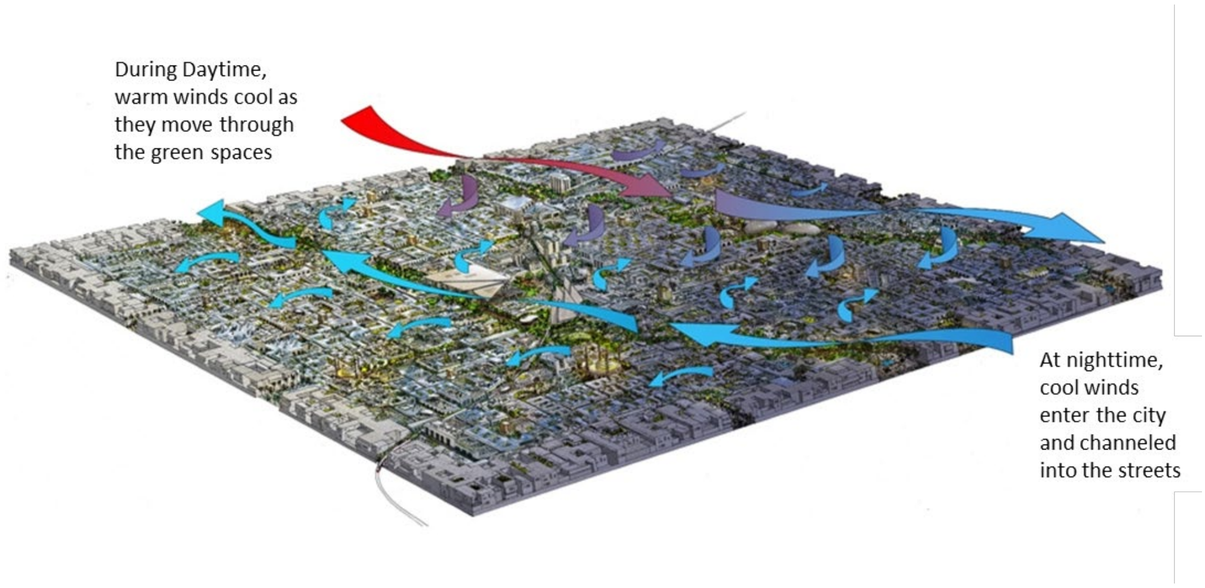


Fig 11: Analyzing air movement during day and night times. (Visualized by Foster+Partners).

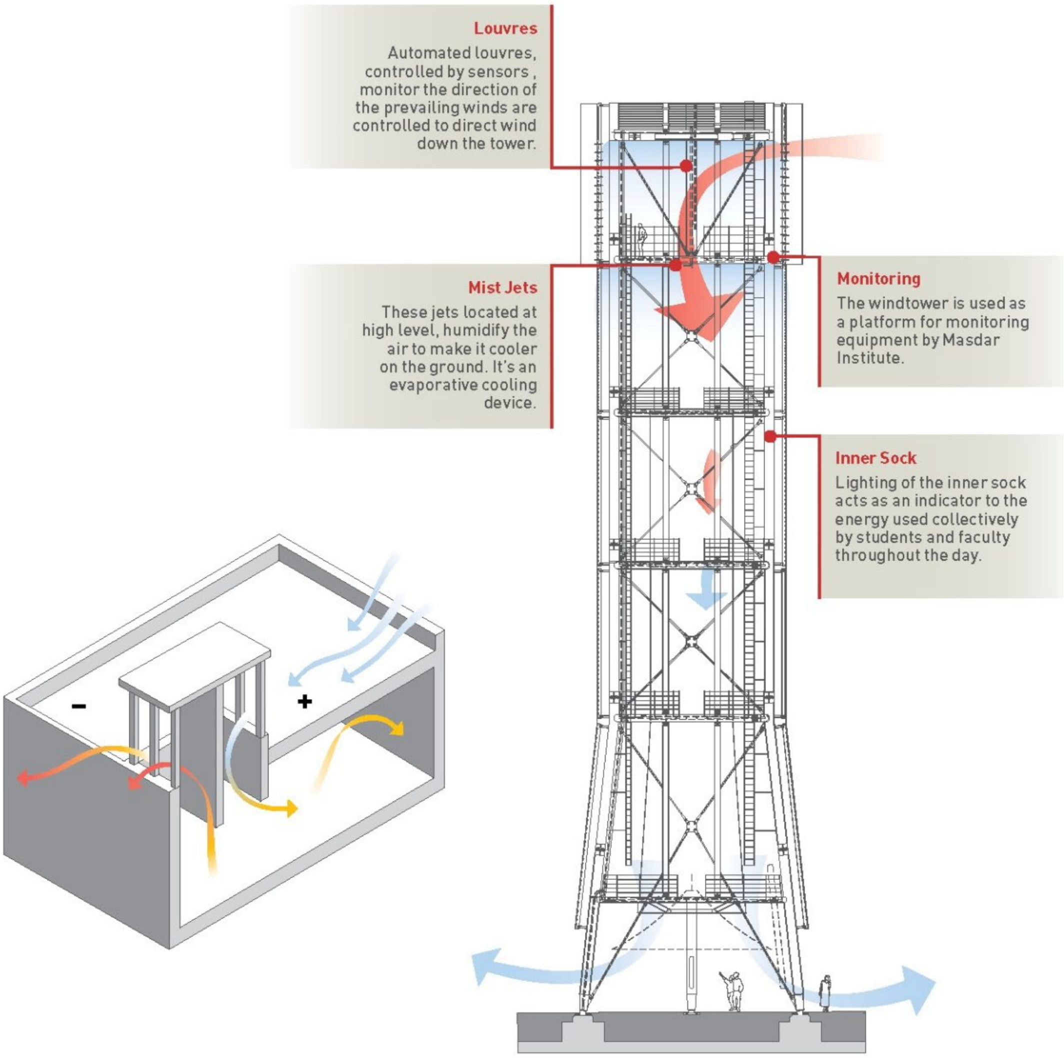


Fig 12: The working mechanism of solar chimney (on right) compared to a traditional one (on left). (Analyzed by Foster+Partners).

Fig 13: Masdar institute central courtyard and the wind tower. (Copyrights: Nigel Young/ Foster+Partners)

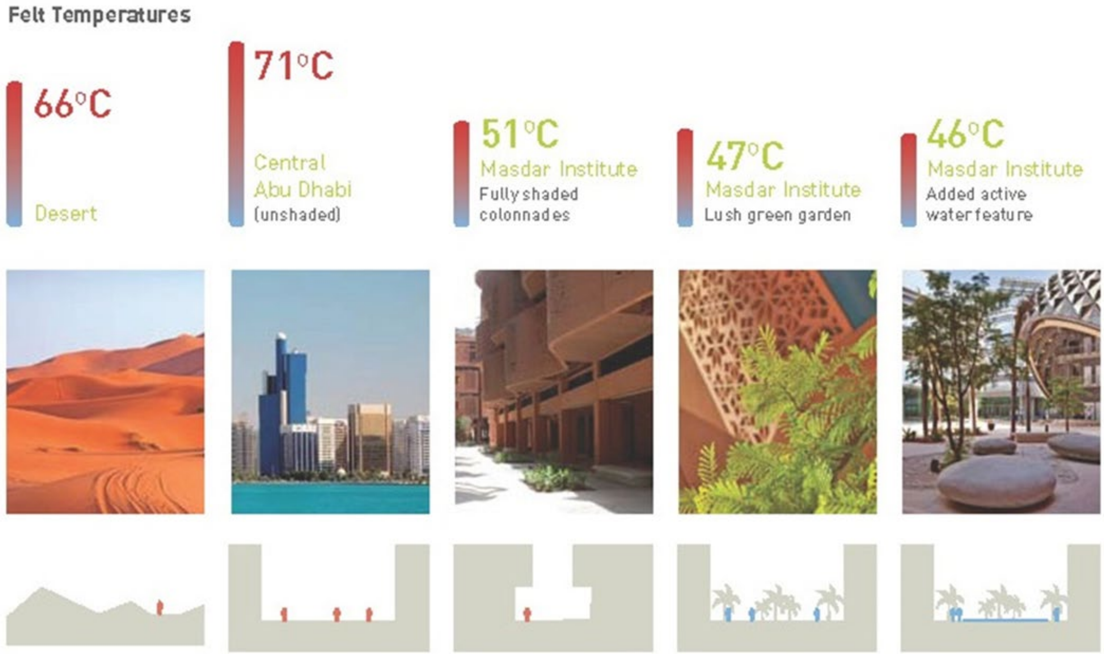


Fig 14: Temperature difference by places: a comparison between Masdar institution and Abu Dhabi city, (The effect of passive cooling strategies and material selections).

(Copyrights: Masdar)

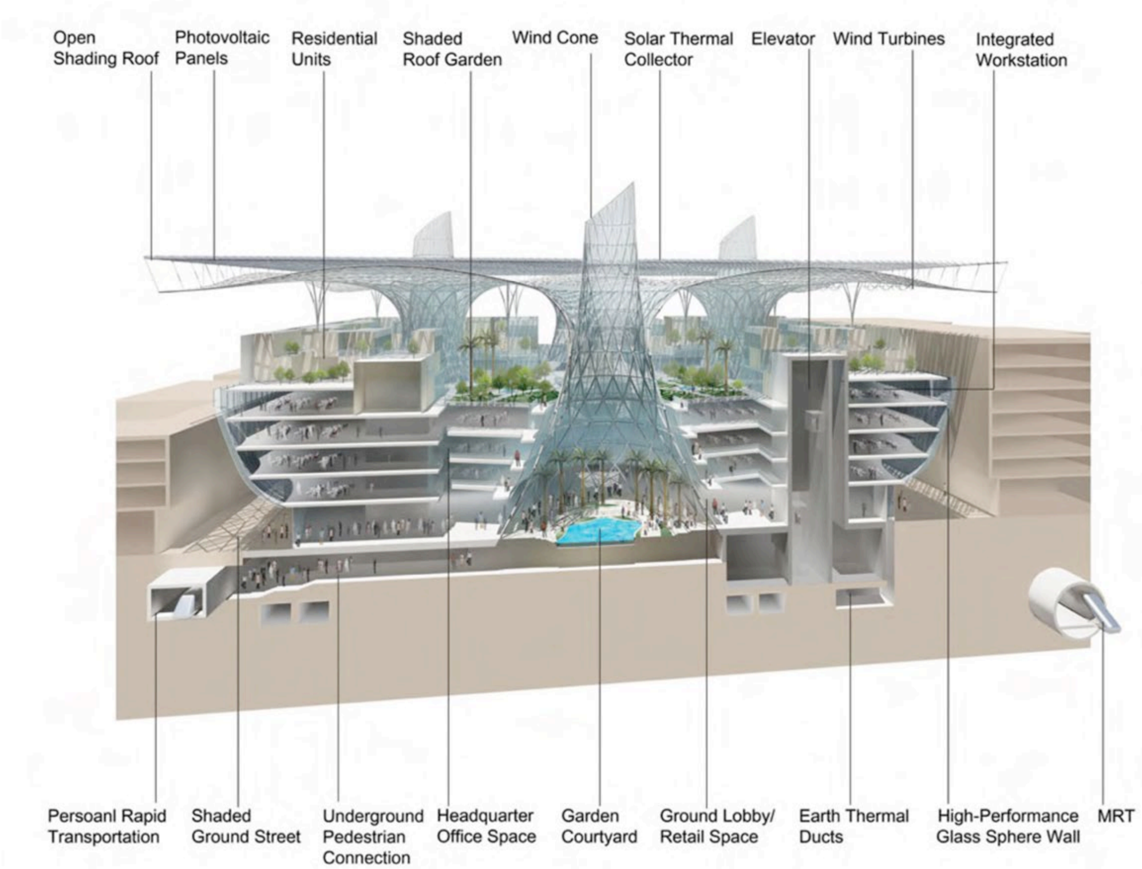


Fig 15: Passive cooling techniques has been applied to the design of Masdar headquarters designed by Adrian Smith + Gordon Gill.

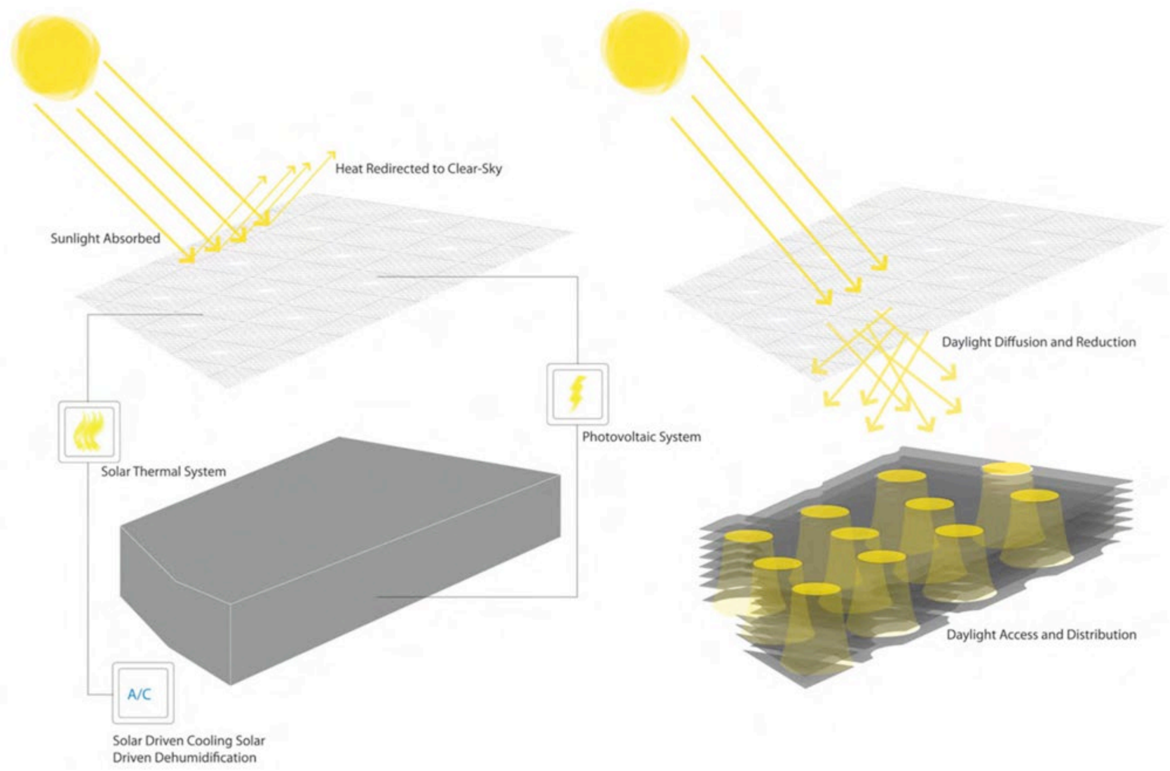


Fig 16: The roof canopy as a shading element and a solar collector element in Masdar headquarters. (Copyrights: Adrian Smith + Gordon Gill).

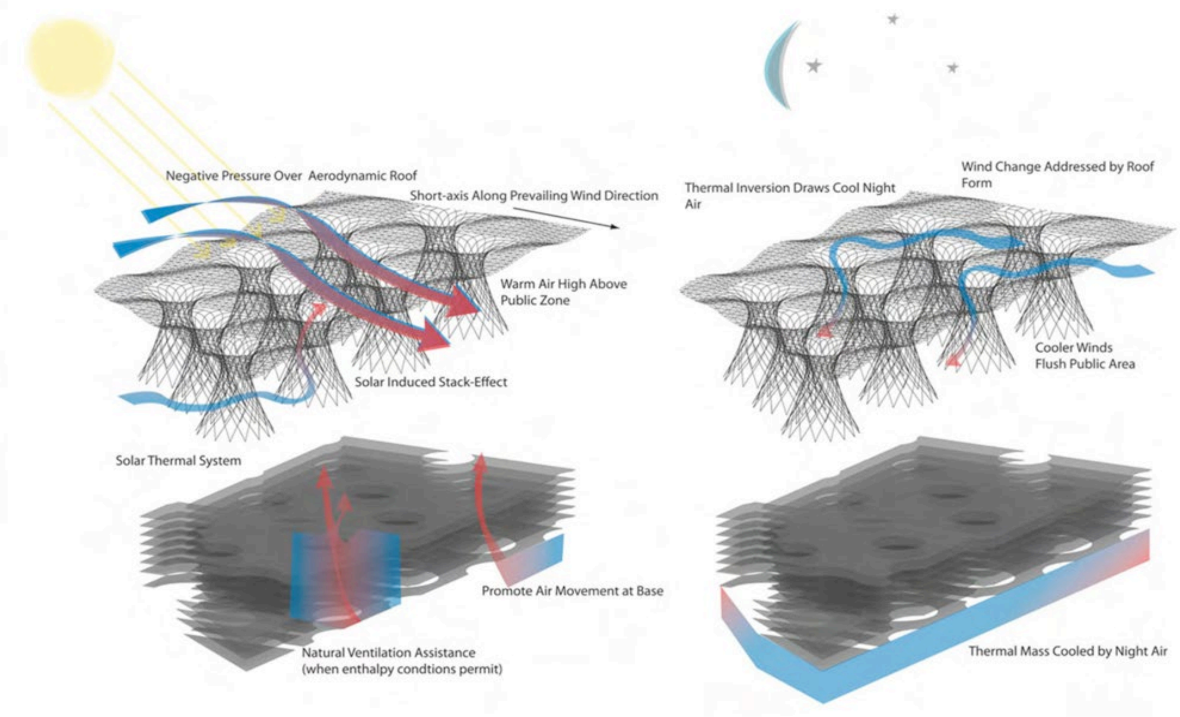
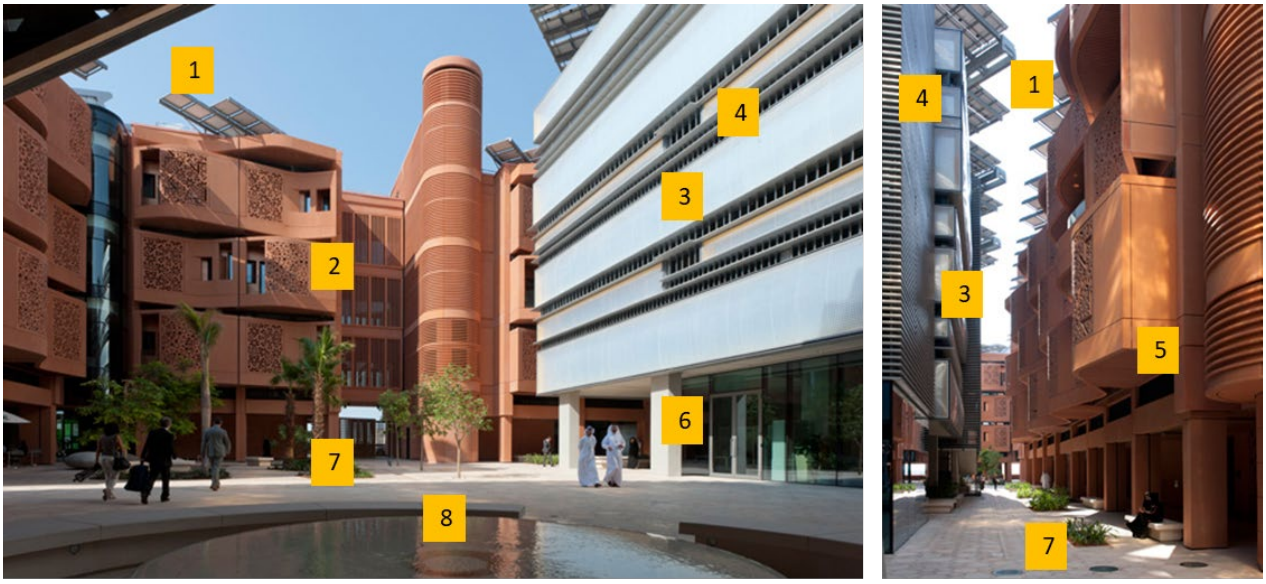


Fig 17: Natural ventilation cooling through wind cones during the day and at night, Masdar headquarters designed by Adrian Smith + Gordon Gill.

Sustainable Materials:

- 100% sustainable timber
- 100% recycled steel reinforcing bars
- Healthy water-based paints with no volatile organic compounds
- 90% recycled-content aluminum for interior faces
- 30-40% reduction in concrete CO2 emissions through the use of green concrete, incorporating ground granulated blasted slag
- ETFE inflatable cushions made of lightweight polymer, reflecting light and absorbing heat for laboratory facades (Masdar 2013)



1. PV panels
2. 2. Shaded Balconies with screen
3. 3. Lightweight EFTE facades, to reflect solar radiation

4. Passive shading elements to filter and control solar radiation
5. Balconies shade pedestrian paths

6. Heavy weight finishes provide thermal mass
7. And 8. Landscaping and water ponds cool the outdoor environment

Fig 18: Masdar institute's material selection and passive cooling strategies. (Copyrights: Nigel Young/ Foster+Partners)

Water Efficiency:

Masdar City employs solar energy desalination systems for desalinating seawater, providing the city with a sustainable source of fresh water. The water system incorporates efficiency techniques, including smart water meters notifying users of consumption amounts and identifying leakage points. Rainwater harvesting and wastewater recycling, treated for irrigating desert plant landscapes through a high-efficiency micro-irrigation system, have collectively reduced water consumption by 60% (Masdar 2011, 16).

Fig 19: Water efficiency of Masdar institute compared to the average consumption of business buildings in Abu Dhabi.

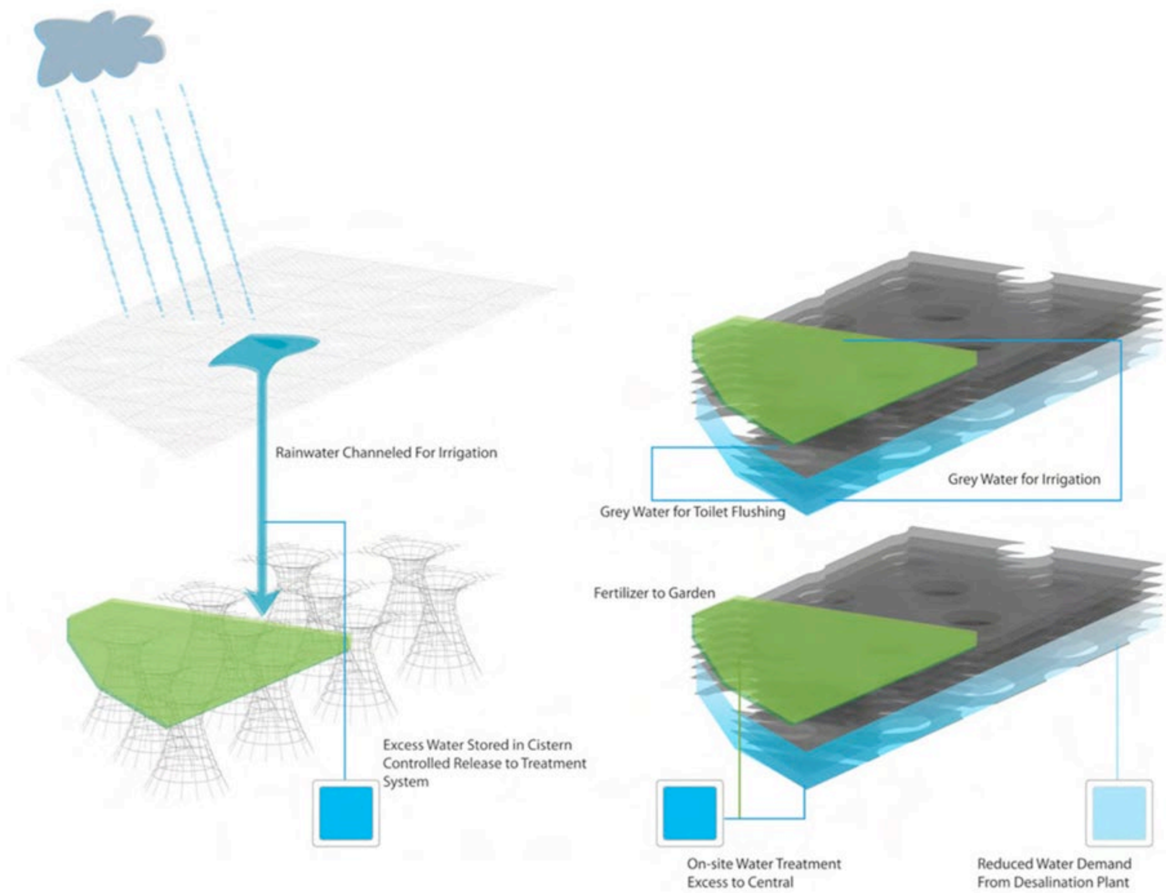


Fig 20: Masdar headquarters' roof canopy water collection strategy and integration with gray water recycling.

(Copyrights: Adrian Smith + Gordon Gill).

Renewable Energy and Efficiency:

Fred Moavenzadeh, head of Masdar Institute and a Harvard professor, states, "The shock of having to conserve energy is part of the Masdar human experiment. We are living and experiencing what we are trying to … educate people about … We're using roughly half the energy of a normal building of this size. We are producing no carbon because it's all renewable" (Vidal 2011).

Power generation comes from over 5000 square meters of photovoltaics installed on building roofs and the Masdar solar power plant located outside the city, using mirrors to concentrate the sun and heat water to generate power. The power plant system is projected to reduce CO_2 emissions by 15,000 tons annually, saving around $50 million (Carvalho 2009). Excess generated power is fed into the national electric grid. Sustainable practices include electric cars and intelligent HVAC and lighting sensor controls.

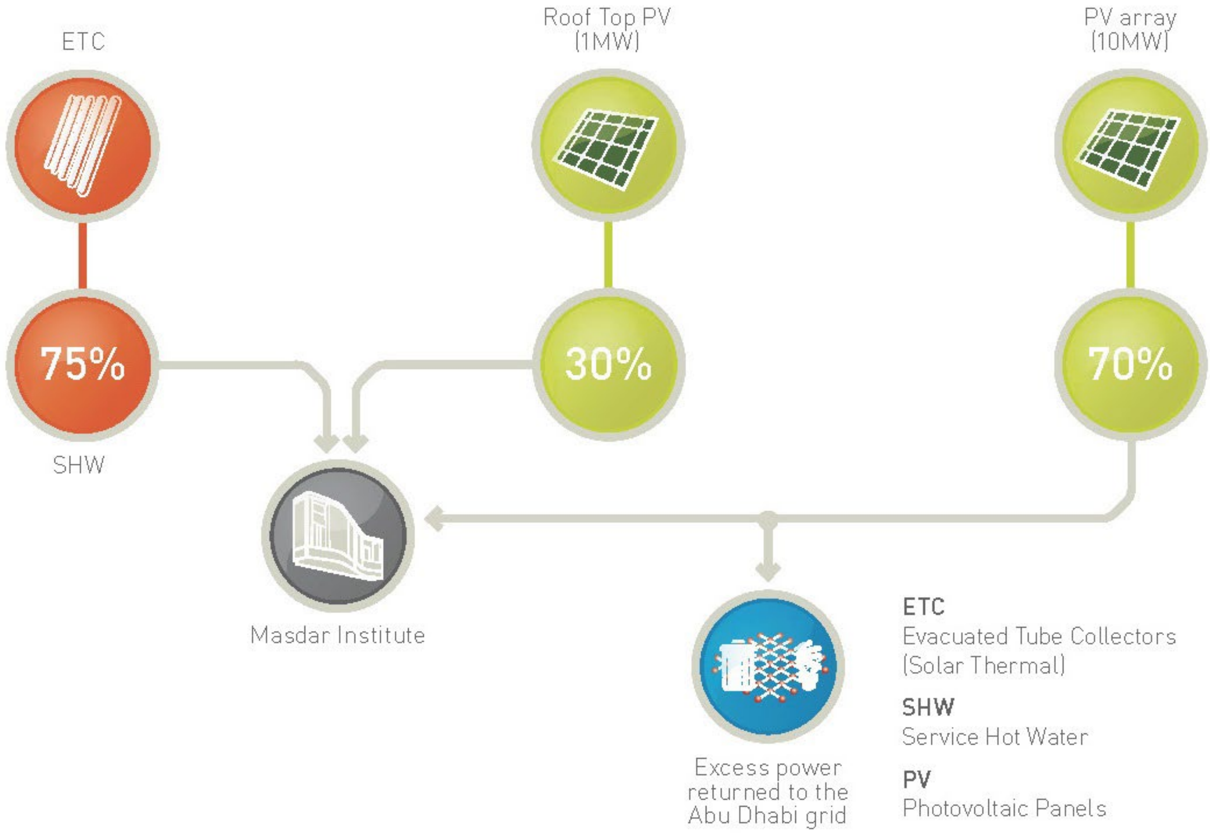


Fig 21: Renewable energy generation sources of Masdar city and Masdar institute.

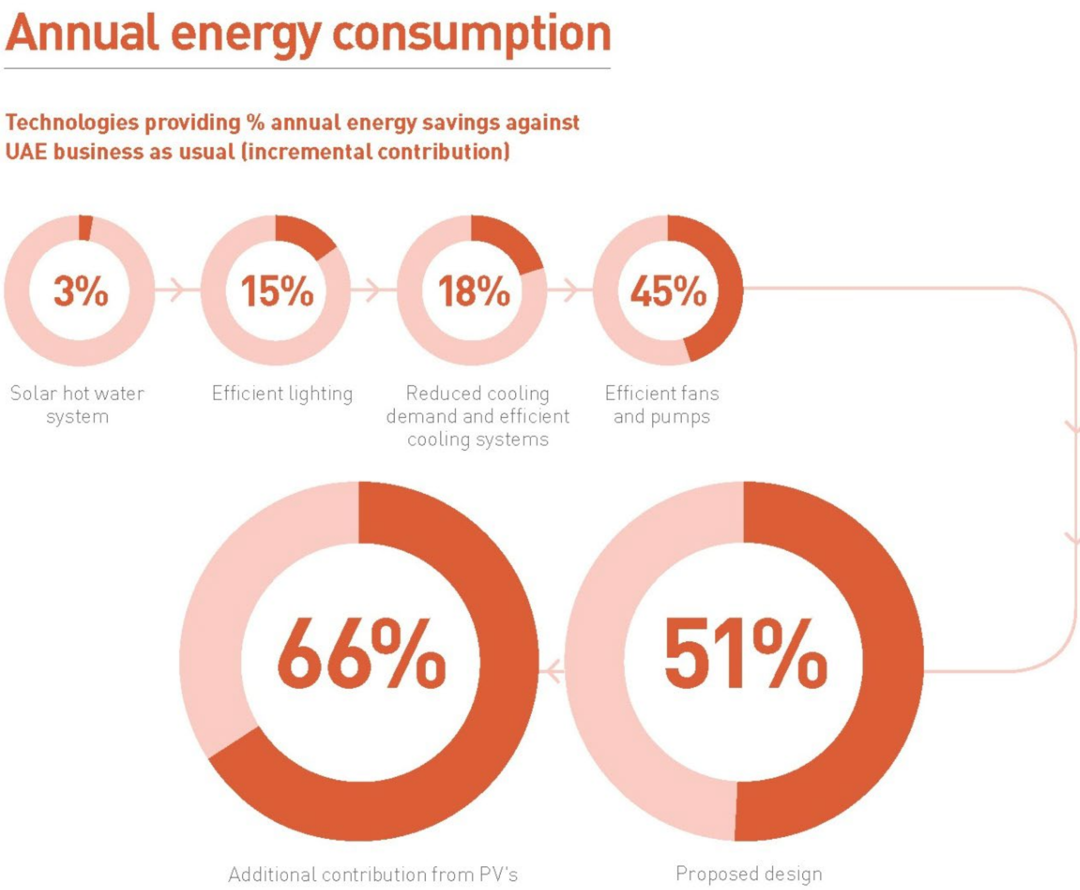


Fig 22: Energy efficiency of Masdar institute compared to the average consumption of business buildings in Abu Dhabi.

Sustainable Operating:

In Masdar City, actions of residents and machines are monitored and recorded by a smart grid of sensors to control energy consumption within limits. This includes regulating lighting, temperature, water usage, and even appliances like fridges and showers. Almost all of the city's generated waste is either reused or composted.

Sensitive facades to climate change, capable of modifying vertical and horizontal angles and orientation, use materials with minimal embedded energy to avoid overheating and minimize heat gain.

The flexibility of the project, along with redesigning and reanalyzing the master plan, has contributed to achieving better results. Dale Rollins, Masdar's chief operating officer, remarked, "The Masdar master plan is changing as the world economy changes. It's unfair to say that what was decided in 2006 will hold forever. The objectives have not changed, but we have reworked the master plan. The technology and the market have moved on. We say we can do it better and we can do it in less expensive ways" (Vidal 2011).

Fig 23: An example of the electric cars used in Masdar city

Fig 24: Recycling and waste strategy at Masdar institute campus

Fig 25: Aerial View of Masdar city from the east side. (Rendered by Foster+Partners).

Discussion

Flexibility in Design: A Double-Edged Sword

The evolution of Masdar City's design, marked by substantial changes in its initial plans, underscores the project's adaptability. Shifting from rooftop solar panels to an external solar panel field exemplifies the responsiveness to economic considerations. While this flexibility is commendable, it also raises questions about the initial planning phases. The ability to optimize the project based on practical considerations reveals the dynamic nature of sustainable development initiatives.

Community Role: A Missing Piece in the Sustainability Puzzle

Masdar City's development, while a triumph of sustainable architecture, lacks a fundamental element: community involvement. The city's construction without a predefined community role suggests a top-down approach that neglects the integration of residents' needs and behaviors. The notion that occupants must conform to the city's design raises questions about the long-term sustainability of such a model. The success of sustainable communities relies not only on architectural brilliance but also on the active engagement and adaptation of the people who inhabit them.

Technology's Dilemma: Efficiency vs. Practicality

Masdar City's experience highlights a crucial paradox: the limitations of high-tech solutions. The decision to build a solar panel field outside the city, rather than on building roofs, is a stark example. While high-tech solutions align with the city's futuristic vision, the practical challenges posed by sandstorms reveal the importance of considering environmental factors in technology choices. This nuanced reality challenges the assumption that cutting-edge technology is always the most efficient solution.

Financial Realities: The Cost of Sustainability

The exorbitant costs associated with Masdar City raise critical concerns about the scalability of such projects on a global scale. While the city serves as a pioneering example of sustainable urban development, its price tag places it out of reach for many regions facing similar environmental challenges. The financial feasibility of replicating Masdar City's success becomes a substantial obstacle, emphasizing the need for cost-effective solutions that can be adopted globally.

Isolationist Approach: A Flaw in the Vision

Masdar City's construction from scratch, coupled with its isolationist philosophy, reflects a utopian vision of sustainability. The idea that true harmony can only be achieved by isolating the community from the external world raises socio-economic questions. Ignoring the economic and social aspects of sustainability, Masdar City's approach may not be replicable in more populous and diverse urban settings. True sustainability requires not just environmental harmony but a balance that considers economic, social, and cultural factors.

Conclusion:

The Middle East, amidst the complexities of rapid development, is actively charting a course towards a sustainable future. Through a comprehensive approach that harmonizes economic growth with ecological responsibility, the region seeks to address the challenges posed by climate change, resource scarcity, and environmental degradation. A shining example of this commitment is Masdar City, a testament to the potential of green projects in fostering an environmentally conscious Middle East. The journey towards sustainability demands ongoing collaboration, innovation, and a shared dedication to preserving the delicate equilibrium between society, environment, and economy.

Masdar City stands as a beacon of innovation and environmental consciousness, unraveling profound lessons for the future of sustainable urban development. Its success is underpinned by meticulous considerations extending beyond architectural brilliance.

Environmental Precision and Technological Integration:

Masdar City's success emanates from its foundation in an in-depth study of the microclimate, demonstrating the significance of aligning designs with the natural environment. The integration of traditional and modern architectural techniques, coupled with cutting-edge tools like Building Information Modeling (BIM), showcases the power of technology in optimizing building performance. This amalgamation not only ensures sustainability but also serves as a testament to the adaptability of design methodologies.

Flexibility and Collaboration:

The evolution of Masdar City's design underscores the importance of flexibility and adaptability in sustainable projects. The architects' keen understanding of vernacular and traditional techniques enriches their design palette, creating a harmonious blend of the old and the new. The collaboration between designers and stakeholders, coupled with a shared vision, is imperative for the success of sustainable initiatives. A dynamic, evolving approach, capable of accepting temporary changes, ensures the longevity and relevance of such projects.

Triple Bottom Line Approach:

Masdar City's holistic success lies in embracing the triple bottom line approach, where the environment, community, and economy are integral components of the design process. Sustainable development, as exemplified by Masdar City, requires a delicate balance that considers not only the ecological impact but also the socio-economic dynamics of the community it serves. This comprehensive approach ensures that sustainability is not just a theoretical concept but a lived experience for the city's occupants.

Continuous Learning and Global Impact:

The incorporation of the latest technological advancements, water and energy efficiency tools, and low-energy lighting systems underscores the importance of continuous learning in the field of sustainable architecture. The global impact of projects like Masdar City is undeniable, setting benchmarks for green initiatives that transcend geographical boundaries. The Middle East, with its unique environmental challenges, stands to benefit significantly from more such endeavors to reduce CO_2 emissions and foster a more environmentally friendly future.

In conclusion, Masdar City's journey provides a roadmap for future sustainable projects, emphasizing the need for precision, technological integration, flexibility, collaboration, and a holistic approach. As we celebrate the triumphs of Masdar City, we also embrace the ongoing challenge to create a sustainable future that not only respects the environment but also nurtures thriving communities and resilient economies. The lessons learned from Masdar City pave the way for a new era of sustainable development, inviting architects, designers, and policymakers to join hands in building a greener and more sustainable world.

List of Images

Fig 11: Analyzing air movement during day and night times.

Reproduced from Masdar City Master Plan. Accessed April 27, 2013. http://www.american-architects.com/en/projects/38846_masdar_city_master_plan/all/featured

Fig 12: The working mechanism of solar chimney compared to a traditional one.

Reproduced from Exploring the Masdar Institute Campus. Accessed April 27, 2013. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/

Fig 13: Masdar institute central courtyard and the wind tower.

Reproduced from Masdar city image gallery. Accessed April 27, 2013. http://masdarcity.ae/en/48/resource-centre/image-gallery/?gal=4

Fig 14: Temperature difference by places: a comparison between Masdar institution and Abu Dhabi city.

Reproduced from Exploring the Masdar Institute Campus. Accessed April 27, 2013. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/

Fig 15: Passive cooling techniques has been applied to the design of Masdar headquarters designed by Adrian Smith + Gordon Gill.

Reproduced from Abu Dhabi's Masdar Headquarters: The First Positive-Energy Building in the Middle East. Accessed April 27, 2013. http://www.carboun.com/sustainable-design/masdar-headquarters-the-first-positive-energy-building-in-the-middle-east/

Fig 16: The roof canopy as a shading element and a solar collector element in Masdar headquarters.

Reproduced from Abu Dhabi's Masdar Headquarters: The First Positive-Energy Building in the Middle East. Accessed April 27, 2013. http://www.carboun.com/sustainable-design/masdar-headquarters-the-first-positive-energy-building-in-the-middle-east/

Fig 17: Natural ventilation cooling through wind cones during the day and at night, Masdar headquarters designed by Adrian Smith + Gordon Gill.

Reproduced from Abu Dhabi's Masdar Headquarters: The First Positive-Energy Building in the Middle East. Accessed April 27, 2013. http://www.carboun.com/sustainable-design/masdar-headquarters-the-first-positive-energy-building-in-the-middle-east/

Fig 18: Masdar institute, material selection and passive cooling strategies.

Reproduced from Masdar city image gallery. Accessed April 27, 2013. http://masdarcity.ae/en/48/resource-centre/image-gallery/?gal=4

Fig 19: Water efficiency of Masdar institute compared to the average consumption of business buildings in Abu Dhabi.

Reproduced from Exploring the Masdar Institute Campus. Accessed April 27, 2013. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/

Fig 20: Masdar headquarters' roof canopy water collection strategy and integration with grey water recycling.

Reproduced from Abu Dhabi's Masdar Headquarters: The First Positive-Energy Building in the Middle East. Accessed April 27, 2013. http://www.carboun.com/sustainable-design/masdar-headquarters-the-first-positive-energy-building-in-the-middle-east/

Fig 21: Renewable energy generation sources of Masdar city and Masdar institute.

Reproduced from Exploring the Masdar Institute Campus. Accessed April 27, 2013. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/

Fig 22: Energy efficiency of Masdar institute compared to the average consumption of business buildings in Abu Dhabi.

Reproduced from Exploring the Masdar Institute Campus. Accessed April 27, 2013. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/

Fig 23: An example of the electric cars used in Masdar city

Reproduced from Masdar city image gallery. Accessed April 27, 2013. http://masdarcity.ae/en/48/resource-centre/image-gallery/?gal=4

Fig 24: Recycling and waste strategy at Masdar institute campus

Reproduced from Exploring the Masdar Institute Campus. Accessed April 27, 2013. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/

Fig 25: Aerial View of Masdar city from the east side.

Reproduced from Masdar city image gallery. Accessed April 27, 2013. http://masdarcity.ae/en/48/resource-centre/image-gallery/?gal=4

References

Books, Magazines and Printed Journals

1. Bauer, Michael, Peter Mösle, and Michael Schwarz. 2010. *Green Building: Guidebook for Sustainable Architecture.* Heidelberg: Springer-Verlag, 2010.
2. Bullis, Kevin. 2009. "A Zero-Emissions City in the Desert." *Technology Review* 112, no. 2: 56-63.
3. EIA. 2011. *International Energy Outlook 2011.* Washington, D.C.: EIA, 2011.
4. Hartman, Hattie. 2010. "MASDAR." *Architects' Journal* 231, no. 5: 24-33.
5. Roaf,Sue, David Crichton, Fergus Nicol. 2009. *ADAPTING BUILDINGS AND CITIES FOR CLIMATE CHANGE.* Second Edition. Oxford: Architectural Press, 2009.
6. Roaf, Sue, Manuel Fuentes, and Stephanie Thomas. 2007. *ECOHOUSE: A DESIGN GUIDE.* Third Edition. Oxford: Architectural Press, 2007.
7. Steele, James, and Hassan Fathy. 1997. An architecture for people: the complete works of Hassan Fathy / James Steele. New York: Whitney Library of Design, 1997.
8. The World Bank. 2012. *World development indicators 2012 The World Bank*. Washington, D.C.: World Bank, 2012.
9. World Commission on Environment and Development. 1987. *Our common future / World Commission on Environment and Development*, chapter 2. Oxford: Oxford University Press, 1987.

Online Articles and Websites

1. Carvalho, Stanley. 2009.” First Solar to help power UAE "green" city.”*Reuters*, January 15. Accessed April 28, 2013. http://www.reuters.com/article/2009/01/15/us-emirates-masdar-solar-idUSTRE50E41T20090115?feedType=RSS&feedName=environmentNews.
2. Foster and Partners. 2013a.”Masdar Development.” Accessed April 28. http://www.fosterandpartners.com/projects/masdar-development/
3. Heap, Tom. 2010. “Abu Dhabi's 'green' city Masdar.” *BBC News*, March 28. Accessed April 28, 2013. http://news.bbc.co.uk/go/pr/fr/-/1/hi/world/middle_east/8586046.stm.
4. Masdar city. 2011.”Exploring the Masdar Institute Campus”. Last modified, April. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/.
5. Masdar city. 2013. “Sustainability and the city.” Accessed April 28. http://masdarcity.ae/en/30/sustainability-and-the-city/.

6. MECSD. 2013. “Welcome to MECSD.” Accessed April 28. http://www.mecsd.com/default.asp.
7. Vidal, John. 2011.” Masdar City – a glimpse of the future in the desert.” *The Guardian,* April 26. Accessed April 28, 2013. http://www.guardian.co.uk/environment/2011/apr/26/masdar-city-desert-future.
8. Yassine, Wissam, and Karim Elgendy. 2011.”Passive Cooling: Responding to Electricity Demand in the UAE.” *Carboun,* September 14. Accessed April 28, 2013. http://www.carboun.com/sustainable-design/passive-cooling-responding-to-uae%E2%80%99s-soaring-electricity-demand/.

Bibliography

Books, Magazines and Printed Journals

1. Bauer, Michael, Peter Mösle, and Michael Schwarz. 2010. *Green Building: Guidebook for Sustainable Architecture.* Heidelberg: Springer-Verlag, 2010.
2. Bullis, Kevin. 2009. "A Zero-Emissions City in the Desert." *Technology Review* 112, no. 2: 56-63.
3. EIA. 2011. *International Energy Outlook 2011.* Washington, D.C. : EIA, 2011.
4. Hartman, Hattie. 2010. "MASDAR." *Architects' Journal* 231, no. 5: 24-33.
5. Roaf, Sue, David Crichton, Fergus Nicol. 2009. *ADAPTING BUILDINGS AND CITIES FOR CLIMATE CHANGE.* Second Edition. Oxford: Architectural Press, 2009.
6. Roaf, Sue, Manuel Fuentes, and Stephanie Thomas. 2007. *ECOHOUSE:A DESIGN GUIDE.* Third Edition. Oxford: Architectural Press, 2007.
7. Steele, James, and Hassan Fathy. 1997. An architecture for people: the complete works of Hassan Fathy / James Steele. New York: Whitney Library of Design, 1997.
8. The World Bank. 2012. *World development indicators 2012 The World Bank*. Washington, D.C.: World Bank, 2012.
9. World Commission on Environment and Development. 1987. *Our common future / World Commission on Environment and Development*. Oxford: Oxford University Press, 1987.

Online Articles and Websites

1. Carvalho, Stanley. 2009." First Solar to help power UAE "green" city."*Reuters*, January 15. Accessed April 28, 2013. http://www.reuters.com/article/2009/01/15/us-emirates-masdar-solar-idUSTRE50E41T20090115?feedType=RSS&feedName=environmentNews.
2. Foster and Partners. 2013a."Masdar Development." Accessed April 28. http://www.fosterandpartners.com/projects/masdar-development/
3. Heap, Tom. 2010. "Abu Dhabi's 'green' city Masdar." *BBC News*, March 28. Accessed April 28, 2013. http://news.bbc.co.uk/go/pr/fr/-/1/hi/world/middle_east/8586046.stm.
4. Masdar city. 2011."Exploring the Masdar Institute Campus". Last modified, April. http://www.masdarcity.ae/digitalbrochure/en/ExploringTheMasdarInstituteCampus/.
5. Masdar city. 2013. "Sustainability and the city." Accessed April 28. http://masdarcity.ae/en/30/sustainability-and-the-city/.

6. MECSD. 2013. “Welcome to MECSD.” Accessed April 28. http://www.mecsd.com/default.asp.

7. Vidal, John. 2011.” Masdar City – a glimpse of the future in the desert.” *The Guardian,* April 26. Accessed April 28, 2013. http://www.guardian.co.uk/environment/2011/apr/26/masdar-city-desert-future.

8. Yassine, Wissam, and Karim Elgendy. 2011.”Passive Cooling: Responding to Electricity Demand in the UAE.” *Carboun,* September 14. Accessed April 28, 2013. http://www.carboun.com/sustainable-design/passive-cooling-responding-to-uae%E2%80%99s-soaring-electricity-demand/.