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High Performance Buildings in Hot Arid Regions– A Case Study for the Siemens Building in Masdar City

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Abstract: A main common characteristic of hot and arid regions is the relatively high radiation and ambient temperatures combined with low precipitation levels. Buildings in such regions, if designed properly and according to proper climate response, will have the potential of improving indoor comfort while significantly minimizing the energy consumption; up to 60% of energy consumption can be traced back to air conditioning. Masdar City, a low-carbon urban development is being currently built in the suburbs of Abu Dhabi, the capital of the United Arab Emirates.One of the city's new buildings, recently delivered, is the Siemens building. The building is designed to achieve a 46% energy usage reduction compared to ASHRAE 90.1-2007 baseline, through enhanced envelope design, highly efficient HVAC and lighting systems, exceptional daylighting features and other both passive and active design strategies, while maintaining the cost at par with other comparable buildings in the region. Recently it was awarded with the LEED Core and Shell Platinum certification- making it the first building to earn this certificate in the United Arab Emirates' capital city; the building is also aiming at obtaining 3 Pearls, according to Abu Dhabi's Urban Planning Council's Estidama rating scheme. The objective of this article is to introduce and discuss all the key features, from the inception of the project to its implementation that contributed to the significantly high energy performance of the building. We will explicitly highlight all the interventions that reflect the specific climate conditions in this hot and arid region.

Key Words: hot and arid climate, High performance buildings, passive design, energy efficiency, Masdar City Siemens Building

1. Introduction

Climate has a major effect on the performance of buildings and their energy consumption. Reducing energy use and providing comfortable, healthier and sustainable living spaces are the aims of a climatically responsive sustainable building design. Nowadays, eco-friendly design and construction strategies that focus on Demand Side Management (DSM) applications and promote Energy Efficiency (EE) in buildings, are of great importance while voluntary and mandatory energy efficiency standards have been developed to guide the design process.

By adopting specific characteristics to a new building's design that respond to the special features of the climatic zone where it belongs, the performance of the building can be further improved. Simultaneously, the potential of CO_2 abatement from building's operation increases and certainly the costs of its operation can be moderated, in particular in hot and arid regions, where weather is one of the main factors affecting buildings energy consumption.

On January 21st, 2014, a new office building was inaugurated during Abu Dhabi Sustainability Week and World Future Energy Summit and was accredited for its highly improved energy performance. It is the most recent Siemens building, located in Masdar City, Abu Dhabi, shown in Figure 1. Even before its opening, the

Siemens building had already garnered a raft of international awards. In 2012, it was named as the best office building at the coveted MIPIM Architectural Review Future Projects Awards, while the Middle East Architect Awards recognized it as the most sustainable and best office building in the entire Middle East and North Africa (MENA) region in the same year.

The Siemens Buildingis designed to optimize efficiency in environmental, commercial and social terms that is fully integrated within itself and Masdar City. The design intent is to evolve a simple building that has been truly optimized for its environment. The building adopts the best possible passive design solutions, optimizes the efficiency of all systems incorporated within the design and integrates technology at a level that is appropriate and useable.

Masdar City is a sustainable low-carbon, low-waste city currently being built in the suburbs of the capital of the United Arab Emirates. The Siemens building was primarily designed to comply with the minimum requirements of Masdar Energy Design Guideline (MEDGv.3) that was developed specifically to serve as a mandatory framework for designing energy efficient buildings in Masdar City (Masdar, 2011).

The current study, describes the different stages from the inception of the project to the construction and energy performance assessment of the building as well as all its important components strictly related to energy efficiency that contributed to its high energy. The following paragraphs will introduce each one of the special design characteristics of the building that contributed to the mitigation of the impact that the extreme climate characteristics in hot arid regions could have on buildings energy performance.

Figure 1. Photograph of the Siemens office building in Masdar citylooking from the north. [Source: Authors' file].

1.1. Hot and arid climate description

Hot arid or desert climate is an environmentin which precipitation is too low to sustain vegetation, or at most a very scanty scrub. An area that features this climate usually experiences less than 250 mm per year of precipitation(Merriam Webster, 2014) and in some years may experience no precipitation at all.The hot and arid climate is also characterized by very high solar radiation levels and ambient temperatures.

The Siemens building is situated in the United Arab Emirates, in one of the most unreceptive climatic zones on earth with extremely high summer temperatures, limited fresh water and high evaporation rates (St. Clair, 2009). Abu Dhabi in particular, has a hot arid climate, consisting of sunny weather with infrequent rainfall. Wet bulb temperature, can reach 32°C (90°F) whereas dry bulb temperature often exceeds 40ºC (104°F) in summer(Aspinall, 2006).

Figure 2showsdry-bulb and wet-bulb temperature in degreesCelsius, for the suburbs of Abu Dhabi, where Masdar City and Siemens building are located, and Figure 3 shows the Horizontal Solar radiation in $W/m^2$for the same location(Mott MacDonald, 2009). Figure 4 shows the Abu Dhabi hourly climate data plotted on a psychrometric chart in relation with the ASHRAE 55-2004thermal comfort zone based on the Predicted Mean Vote Method.

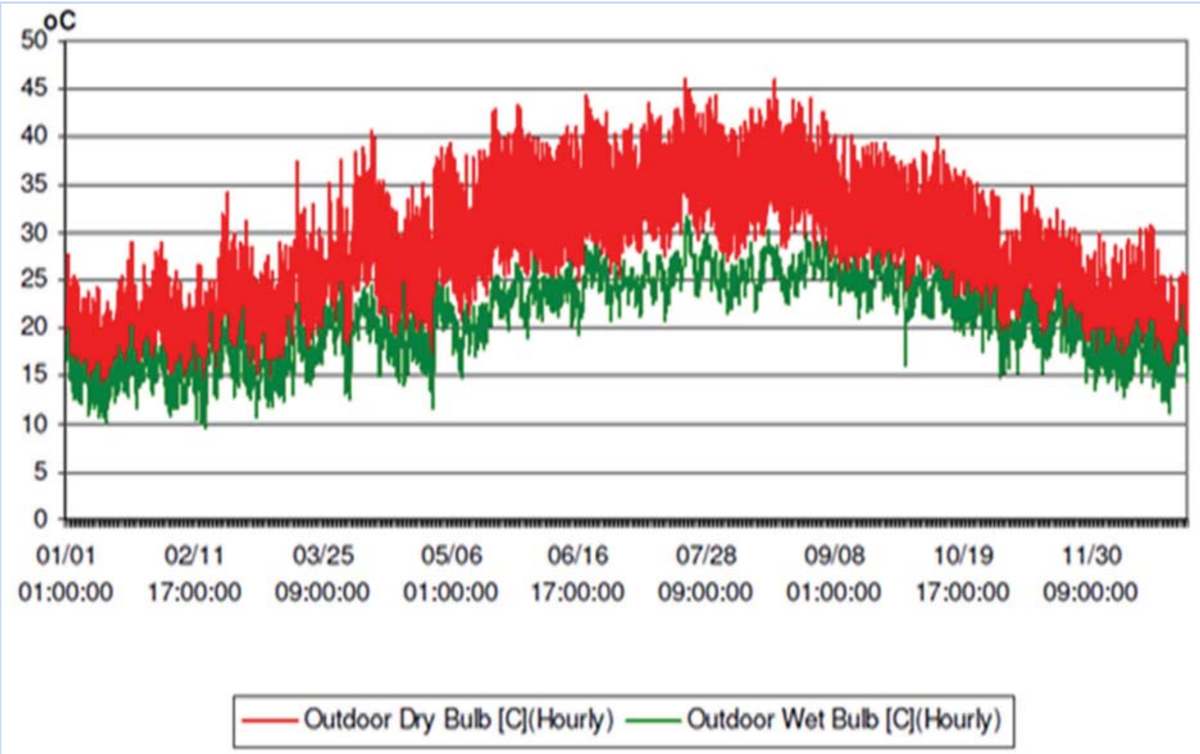

Figure 2- Dry and Wet Bulb temperature in Abu Dhabi (TM2) (whole year).
[Source: Mott MacDonald, 2009].

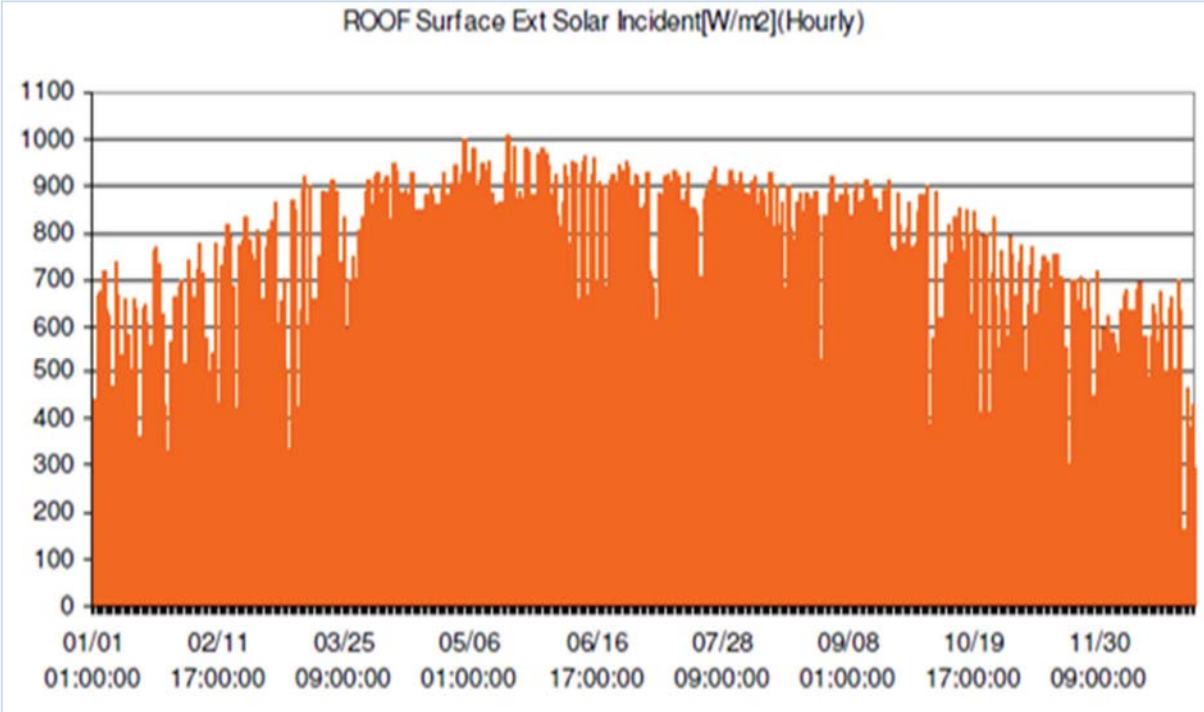

Figure 3. Horizontal solar radiation in Abu Dhabi (TM2) (whole year).
[Source: Mott MacDonald, 2009].

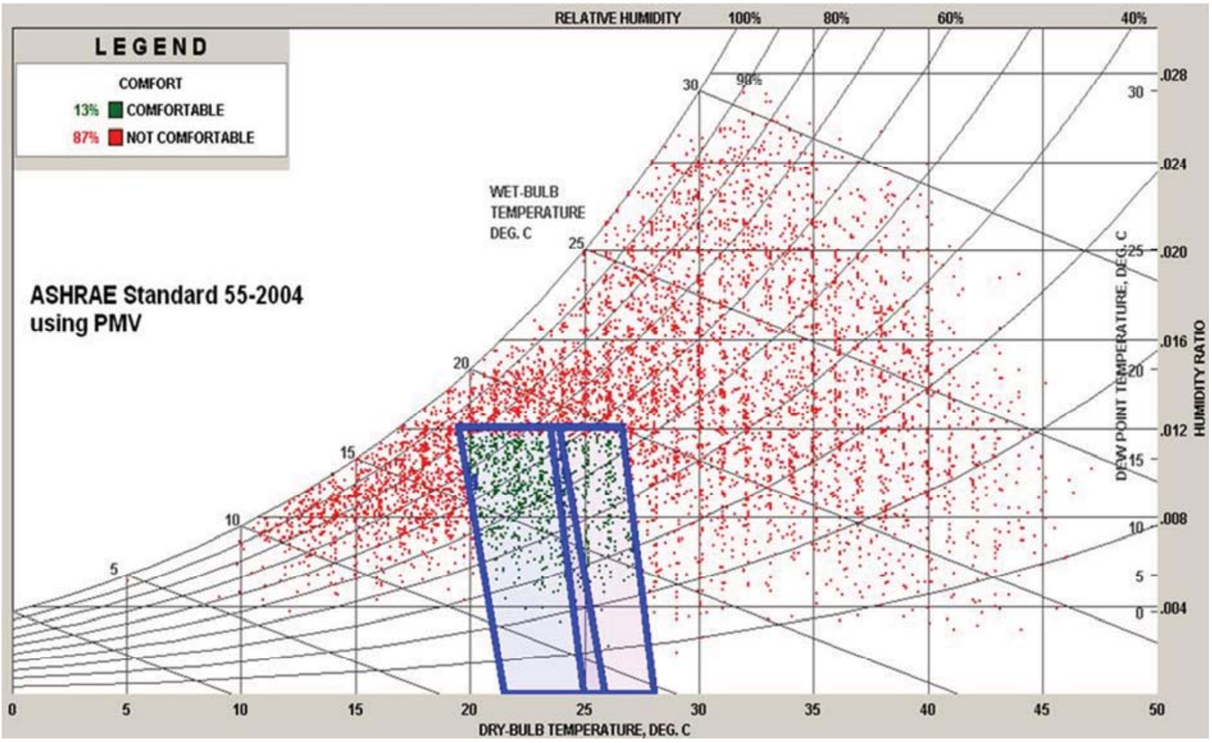

Figure 4- Psychrometric chart with the ASHRAE 55-2004 comfort zone for Abu Dhabi.
[Source: Climate Advisor software].

Based on the above graphs that show high dry-bulb and wet-bulb temperature combined with year round high solar radiation and extensive hours with climate conditions outside thermal comfort zone, one can easily infer that this climate is mainly a cooling-dominated climate and requires negligible heating in winter.

1.2. Case study: Siemens Building in Masdar City: Designing Approach and Proposed Design

Designed by architects Sheppard Robson International, theSiemens Building is one of the most energy-efficient buildings in the region, i.e. based on modeling and simulations the building's annual energy consumption is **109.5 kWh/m^2** (AECOM, Design notes) much lower than Abu Dhabi commercial building Business As Usual which is 333kWh/m^2(ARUP, 2010). As shown in Figure 5 below, based on the concept of a 'box within a box,' the structure has a highly insulated, airtight inner facade designed to reduce thermal conductivity, and a lightweight aluminum external shading system, which minimizes solar heat gains while maximizing daylight and views from the building.

Optimization of energy performance, cost effective design and the development of a spectrum of design options, were the set of tools put forward by the design team to achieve the sustainability targets. To benchmark the design, the proposed building was assessed against EstidamaPBRS as well as the latest set of MASDAR Sustainability KPI's, Masdar Energy Design Guidelines MEDGv.3, and LEED Core & Shell.

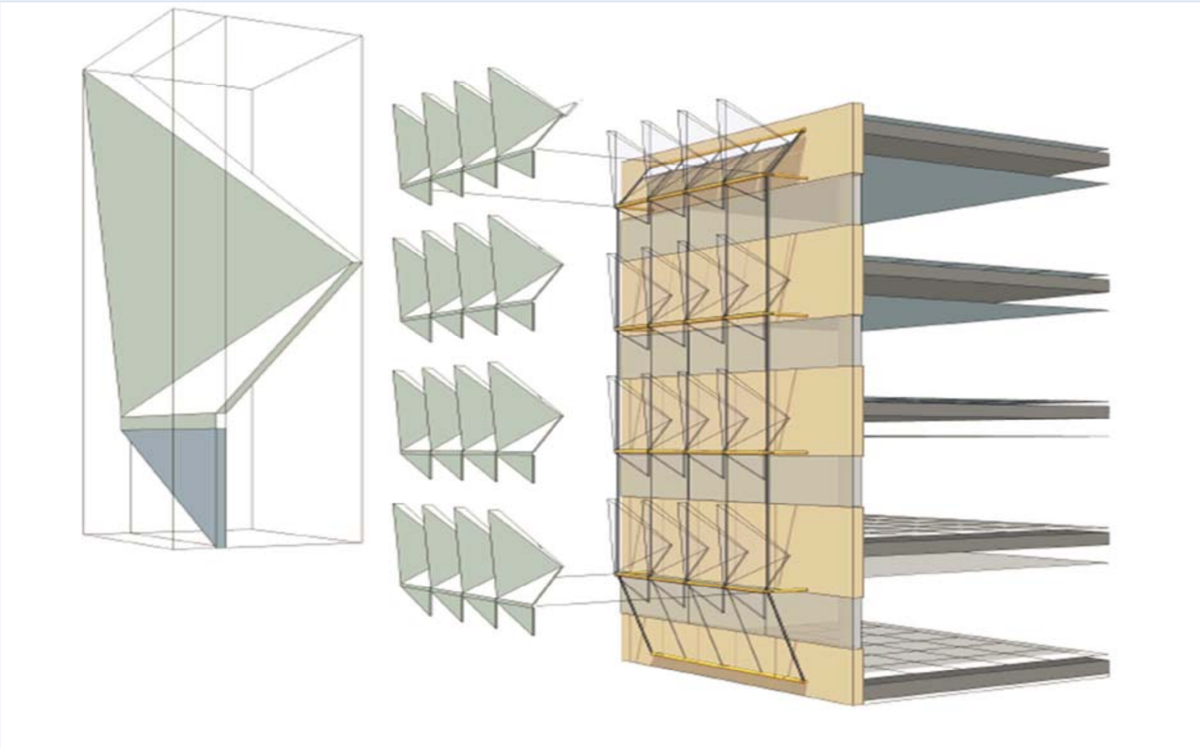

Figure 5. "Box within a box" structure in the case of Siemens Building.
[Source:Sheppard Robson International, Architecture v1: Siemens building, construction documentation stage Report, 2011].

Masdar Energy Design Guideline (MEDG) has been developed specifically to serve as a mandatory framework for designing energy efficient buildings in Masdar City(Masdar, 2011). To ensure that community buildings adhere to the MEDG, two different compliance options are allowed. The first option, the fully prescriptive path, sets out a number of design requirements for new buildings such as maximum window-to-wall ratio, shading, minimum glazing performance, wall & roof insulation, etc. The proposed design has to meet all prescriptive and mandatory requirements in order to comply with MEDG. The second option, the compliance model path, includes some mandatory (prescriptive) design requirements; however, compliance of the proposed design will be demonstrated through energy simulations: a model of the proposed design will be compared to a reference model. Buildings larger than 2,000 square meters in size have to follow the second option.

Indeed, in case of Masdar Siemens building, the compliance model path was followed, however the design team adhered as much as possible to the design requirements prescribed by MEDGv.3.0. As a result, the building complies withMEDGv.3, (by demonstrating 2.9% energy improved performance over the MEDG baseline).

2. Siemens Building: Characteristics, Energy Efficiency Strategies and Design Approach

The Gross Floor Area (GFA) of the building is approximately 24,000 square meters (including 1,000 square meters retail) while the ratio of Net Internal Area (NIA) to GFA is 87%. The building can accommodate around 1,300 tenants which accounts for a population density of almost $18m^2$/person(Sheppard Robson International, 2011).

The Siemens Building was designed to meet the energy targets that were set in the design brief (including MEDGv.3) while maintaining the building cost within the agreed budget. The priority was to fully utilize the building's fabric, through improving the envelope air-tightness and resistance to heat gains while utilizing daylight and maintaining views,thenselecting the right technologies at a level that is appropriate and usable. All decisions related to energy performance were backed up and validated through extensive energy modeling and cost estimating exercises to ensure that all proposed strategies meet the environmental, commercial and social criteria. These key design strategies are summarized in Figure 6 which shows an intermediate design of the Siemens Building.

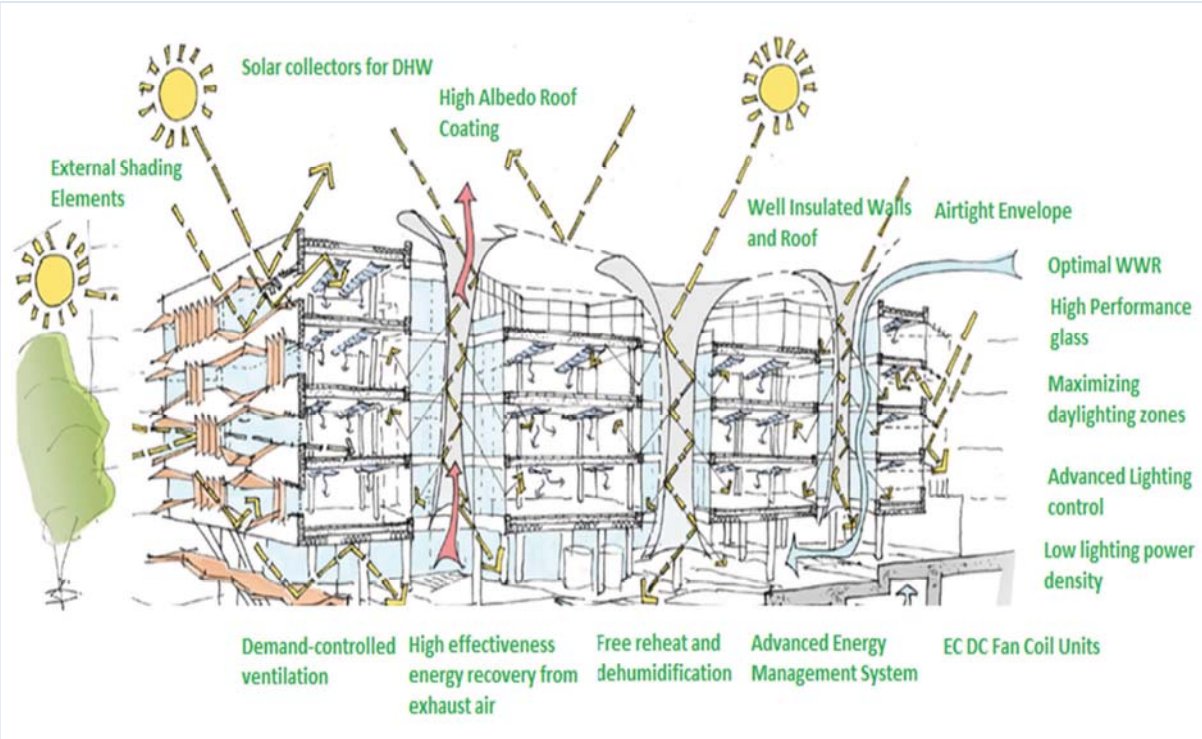

Figure 6- Key Design Strategies adopted in the Siemens building in Masdar city. [Source: Sheppard Robson international].

The main energy efficiency interventions that contributed to the building's high-energy performance are discussed in the following gparagraphs.

2.1 Thermal comfort in vicinity of the building:

The orientation of the Siemens building was set by the Masdar City Masterplan. The whole city has a north-westerly orientation that was determined through wind and solar analysis.

The plaza underneath the Siemens building is shaped like a funnel, rising from ground level at its entrance to the podium that supports the rest of the city. Figure 7, shows a rendering of the Plaza under the Siemens office building. This funnel effectively captures prevailing winds underneath the building, and accelerates them due to Venturi effect, flushing hot air out of the surrounding public spaces. These winds also flow up on to the roof of the building through a series of open atria that puncture the building's structure as sketchily shown in Figure 6.

Not only do the atria act as a ventilating chimney, but also directs daylight into the heart of the building, reducing the need for artificial lighting.

Improved air movement in these shaded spaces coupled with raised office block and the screens and canopies that shade the building reduces apparent temperatures also known as "felt air temperature".This improvesthe outdoor thermal comfort even when actual temperatures are outside the human comfort zone and creates outdoor spaces that are more comfortable all-year round.

Figure 7. Rendering of the Plaza under the Siemens Offices.
[Source:Sheppard Robson International, Architecture v1: Siemens Building, Construction Documentation Stage Report, 2011].

In the following paragraphs of this sections, all the important energy efficiency interventions that contributed to the highly energy efficient performance of the building are discussed.

2.2. Building envelope

The facade must principally perform two functions; the first is to provide an environmental barrier to the outside environment, which effectively contains an isolated internal environment that allows daylight to enter and offers views to the surrounding environment.The second requirement is in direct response to the glazing locations created in the first, and the need to shade the glazed elements of the envelope(Sheppard Robson International, 2011).

In order to optimize each for its purpose, the design team concluded that it is best to isolate them from each other and let each adjust to its brief without compromising the integrity of the other.

The internal box has been designed to be as simple as possible. It is compact and planar in order to reduce surface area in contact with the environment and to minimize waste. It is highly insulated and uses large cladding modules which are prefabricated off site and factory tested to minimize air infiltration.

The glazing has been reduced to approximately 35% Window to Wall Ratio (WWR) and has been located for optimal daylight penetration to the floors, as is shown in Figure 8.

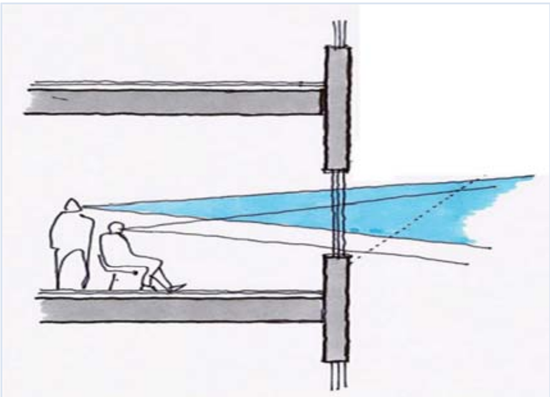

Figure 8.Location of windows is well selected in order to maintain good views of the exterior for the tenants, while balancing the daylight and solar heat gains.

The external finish has a highly reflective and light color to maximize indirect light penetration into the building and minimize heat absorption from direct solar gains. This simple canvas becomes a backdrop to delicate and varying external shading filigree that protects the glazing. In order to minimize on cooling demands within the building,the design team aims to reach almost 100% shading of all glazed areas.

The design of the shading has been parametrically optimized for each orientation of the building elevations. It aims to provide adequate level of shading whilst minimizing horizontal surfaces and material use to maintain the appropriate levels of indirect daylighting to the floors and offer maximum views out. It is made from a selection of materials which either diffuse or redirect light into the internal office floors. They are delicate and highly articulated modular components that cast intricate shadows onto the internal box. As the sun moves around the building these shadows animate the building and give a subtle depth to the external envelope.Figure 9shows the shading elements used for each side of the building as well as at the roof skylights.

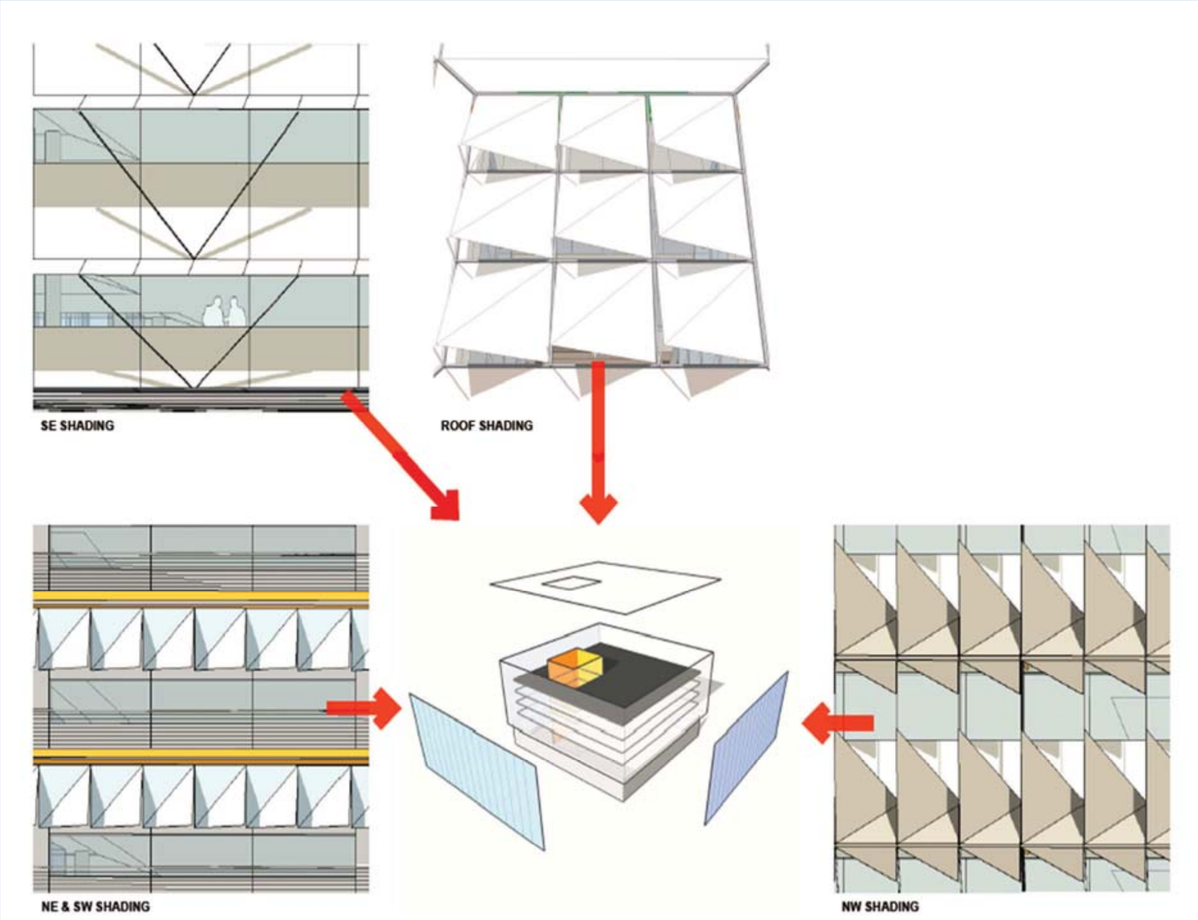

Figure 9. Shading Elements on facades and roof.
[Source:Sheppard Robson International, Architecture v1: Siemens Building, Construction Documentation Stage Report, 2011].

2.2.1 Building envelope conductive performance – opaque elements

The external wall construction to the office areas is an in-situ concrete up stand with an External Insulation and Finish System (EIFS)(Sheppard Robson International, 2011). The system has high thermal insulation using rigid foam boards and a relatively thin finish coat which has low thermal mass, helping to reduce the amount of heat that the building absorbs and re-radiates. High density foam insulation boards are used to insulate the roof.

In Table 1 below, the U-Values of the opaque partitions of the proposed design for the Siemens Building are given in comparison to the ones in of the ASHRAE 90.1-2007 Baseline.

Table 1. Opaque building elements U-values of the building envelope of the proposed design in comparison to those of ASHRAE 90.1-2007 Baseline.

Building Envelope Requirements Opaque Building Elements	Siemens Building U-Value ($W/m^2.K$) (W/m^2K)	ASHRAE 90.1-2007 Baseline U-Value ($W/m^2.K$)
Roofs	0.16	0.36
Above grade walls	0.27	0.705
Opaque swinging doors	3.00	3.975
Opaque non swinging doors	2.50	8.233

2.2.2. High albedo roof coating

The usage of cool roof reduces heat flow into the building hence reducing the cooling load and reduces heat flow emitted to the atmosphere hence moderate the urban heat island effect. In case of Siemens building, roof was coated with high solar reflectance and thermal emmitance material, with Solar Reflectance Index (SRI) exceeding 78(Sheppard Robson International, 2011).

2.2.3 Window to Wall Ratio (WWR)

Fully glazed facades gained popularity during recent years in the Middle Eastregion although the amount of heat introduced to the conditioned spaces due to the large area of glass is considerably high and requires substantial cooling energy. Moreover, ironically, occupants sitting next to such glass walls tend to keep their window blinds down because of excessive glare and heat radiation. Such a trend leads to increased energy consumption and oversizing of the HVAC equipment. In the Siemens building, the window to wall ratio was kept to an average of 35% of gross wall areas as required by MEDGv.3, maintaining a good balance between heat gains, daylight and views.

2.2.4. Glazing properties

The windows are aluminum thermally broken frames with double glazed units. Because the glazing is fully shaded, the glass does not require a low Solar Heat Gain Coefficient (SHGC) value to meet solar control requirements. The glass installed and used in the energy modeling has anappropriateVisible Light Transmission (VLT), in the range of 50%. It is relatively lightly tinted and provides clear views out. Double glazing was used instead of triple glazing because the latter would have been a significantly more costly alternative. No inert gas was used between glass panes because of potential leak in the future. Through the results of energy modeling combined with risk and financial assessment analysis, fixed windows were chosen instead of operable ones mainly because free cooling provided through economizer mode in outdoor air handling units was superior to natural ventilation via operable windows.

In Table 2, the U-Values and SHGC of the glazing used in different parts of the building are listed for the Siemens buildingin comparison to the ones used inASHRAE 90.1-2007 Baseline.

Table 2. U-Values and SHGC of the glazing used in different parts of the building are listedfor the Siemens building, in comparison to the ones used inASHRAE 90.1-2007 Baseline.

GLAZIN G	Siemens Building		ASHRAE 90.1-2007 Baseline	
	U-Value (W/m^2.K)	SHGC	U-Value (W/m2.K)	SHGC
Atrium	1.44	0.420	6.81	0.25
Entrance	1.33	0.434	6.81	0.25
Ribbon	1.95	0.420	6.81	0.25
Retail	1.50	0.409	6.81	0.25
Skylights	1.52	0.413	7.72	0.19

2.2.5 External Shading

External shading was one of the most significant interventions that was adopted for facade design which almost reaches 100% of all glazed areas. Figure 9, below, shows the North-West façade of the building and the fixed shading elements on it. What is important to be highlighted is that the external shading elements are not identical in all façades but different and optimized for each orientation according to the incident radiation characteristics for each facade. The shading elements are lightweight and have a low thermal mass. The external material has a highly reflective and light color to maximize indirect light penetration into the building and minimize heat absorption from direct solar gains.

Design of the shading elements has been parametrically optimized for each orientation of the building elevations. It aims at providing maximum shading whilst minimizing horizontal surfaces and material use to maintain the highest levels of indirect daylighting to the floors and offer maximum views out (AECOM, design notes). It is made from a selection of materials which either diffuse or redirect light into the internal office floors. The northwest façade was the most challenging to shade because its northwest orientation exposes it to low angle sun, therefore shading elements were folded to provide shade but also allow north light to penetrate into the building.

On the other hand, the central roof terrace and the atrium roofs are shaded by a tensile fabric structure. Each shading unit is angled up at the north corner so that they provide shade but allow north light into the atrium and will allow views of the sky. The plane of the shading structure is elevated above the roof light to avoid the buildup of hot air beneath it and allow access to the glazing for cleaning.

Fixed shading elements were selected instead of movable shading elements to minimize the initial cost and maintenance cost while providing adequate energy benefits The externalshading on North-West façade is shown in Figure 10 below.

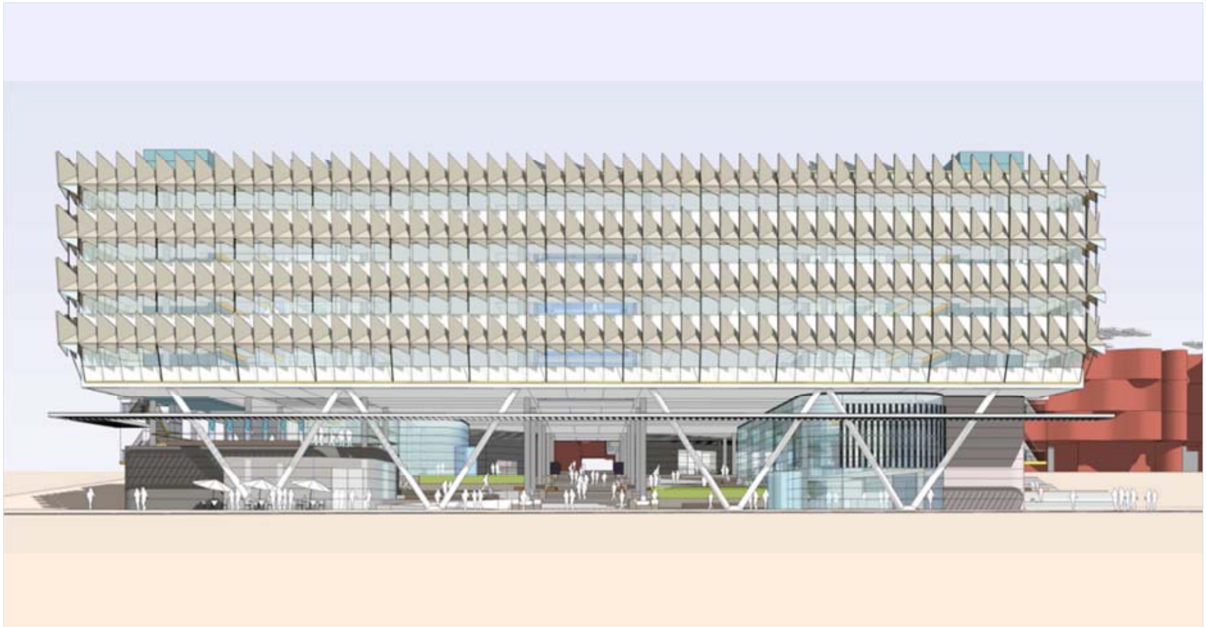

Figure 10. View of North-West façade and shading elements.
[Source:Sheppard Robson International, Architecture v1: Siemens Building, Construction Documentation Stage Report, 2011].

2.2.6. Envelope Air-tightness

The climate in Abu Dhabi is hot and humid, accompanied with occasional sand storms, therefore air leakages through building envelopes need to be minimized to maintain good levels of comfort and energy performance. Envelope air tightness in the Siemens Building was a continuous process throughout the development of the project starting from early design stage. Evaluating all envelope parameters, materials and assemblies was key in order to achieve the MEDG minimum airtightness target of $5m^3/hr.m^2$ of the envelope area of the building, under a pressure differential of 50 Pa in accordance with EN 13829. The envelope air tightness test showed that the building is even tighter compared to the initial target of air permeability standard and achieved anair permeability of 3.7 $m^3/hr.m^2$@50 Pa(Green Building Solutions, 2013).

2.3. Advanced Cooling and Ventilation Systems

The Siemens Building is currently served by Masdar's temporary district cooling systemwhich provides chilled water at 7°C. This plant will be soon replaced by Masdar's permanent district cooling system that will provide chilled water at the same temperature but at a higher efficiency. When the new plant is operational, the Siemens Building energy performance will increase further.

During preliminary design stage, eight different air conditioning systems were evaluated based on cost, energy performance, reliability, life cycle cost, constructability, maintainability, thermal comfort and sound level. Only two systems made it to the next round of evaluation and were subject to more in-depth analysis using energy simulation tools. Finally, Electronically Commutated Direct Current (EC/DC) Fan Coil Units (FCUs) were selected for zonal cooling with outdoor air supplied by variable volume dedicated outdoor air handling units. EC/DC FCUs in the Siemens Building operate with a rated specific fan power of 0.3W/l.s.

Moreover, an advanced ventilation system was used consisting of Dedicated Outdoor Air Handling Units (DOAHU) using "double-wheel" technology to treat the outdoor air supplied to the building's occupied spaces. The "double wheel" system consist of a total energy recovery wheel that recovers up to 80% of the exhaust air's total energy and a passive desiccant wheel that reheats and dehumidifies the outdoor air (Figure 11). All AHU fan motors are equipped with Variable Frequency Drives (VFDs) and designed to meet the minimum system fan powers allowed within by the MEDGv.3(AECOM, design notes). Demand Controlled Ventilation was also specified for densely occupied spaces with a design occupant density greater than or equal to 25 people per 100 m^2(AECOM, *HVAC Systems Selection Design Note, Project: Siemens HQ, Masdar*). CO_2 sensors placed in these spacescontrols the ventilation system to deliver the right amount of outdoor air.

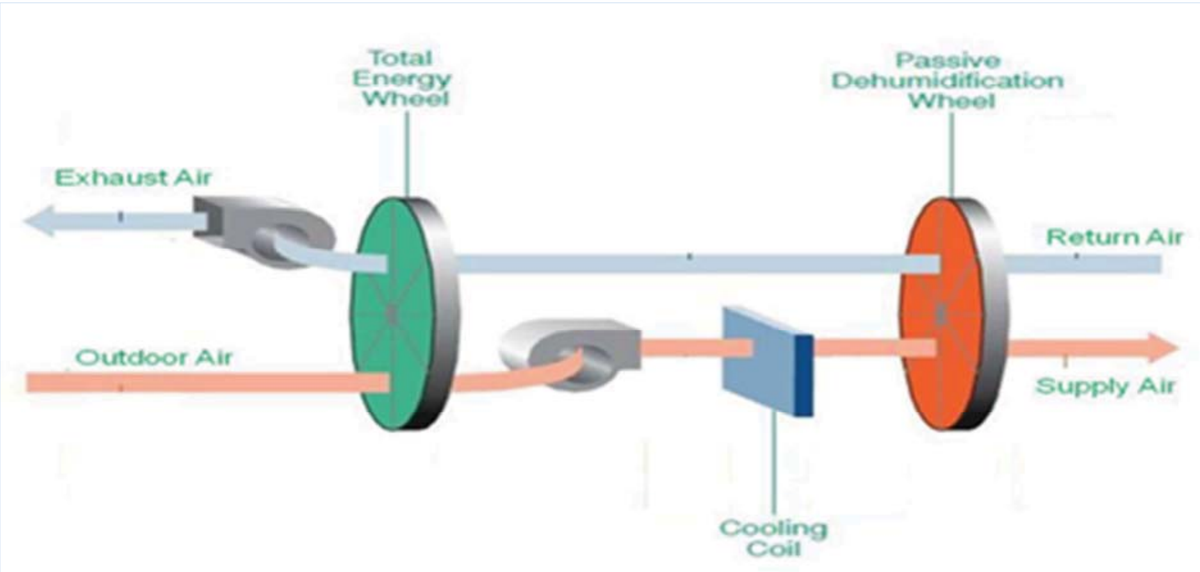

Figure 11.Total energy recovery in line with passive reheat &dehumidification provides higher performance and better IAQ.

2.3. Domestic Hot Water (DHW)

A combination of (28) nos. solar water heating flat plate panels located on the roof generate about 75% of the building's hot water heating requirements over the course of the year (Figure 12). The remaining of the annual hot water demand is provided by centralized electric heaters located on roof. The solar heating system provides clean energy for about 2.75% of the building's annual energy consumption (Sheppard Robson International, design notes).

Figure 11. Simple, robust, easy to clean and cheaper than Evacuated Tube Collector (ETC) yet offering equal energy absorption per unit area

2.4. Lighting

Energy efficient lamps were selected throughout all the building. Light-emitting diode (LED) and florescent lamps are mainly used, achieving an average lighting power density of about 7 W/m^2.

In addition to energy efficient lighting fixtures, an advanced lighting control system isimplemented in the building, comprising of daylighting control, presence control and time schedule.

2.5. Advanced Energy Management System

The Building Management System (BMS) intends to provide several advantages for occupant comfort and energy savings, optimizing the energy efficiency of the HVAC equipment.

A fully developed BMS and an energy management control system using field programmable, microprocessor-based controllers are incorporated in the Siemens Building. System Controllers are provided for local monitoring and control of the different elements of the electro-mechanical services.

Electricity, water and cooling meters are installed on each level and each core of the building and linked to the BMS providing automatic meter reading facilities and real-time analysis. All meters have data logging capability and are connected to a central monitoring system so that information on energy and water consumption is recorded. The monitoring system has the following capabilities:

- Provides hourly, daily, weekly, monthly and annual energy consumption for each end-use.
- Compares consumption to previous days, weeks, months and years for trend analysis.
- Determines “out-of-range” values and alert building operators.

Furthermore, the building has real time LCD displays, at building entrances, of energy and water consumption for promoting public awareness and enabling occupants to see and understand how the building is performing(Sheppard Robson International, design notes).

3. Results and Discussions

The energy performance of the Siemens Building was assessed using energy modeling software from Integrated Environmental Solutions Ltd, version 6.4.0.4. The following results show the energy performance for both the baseline and proposed buildings (the proposed building is the Siemens Building in this case). The proposed building achieved a 46% energy usager eduction compared to ASHRAE 90.1-2007 baseline. The energy modeling simulation was performed based on ASHRAE 90.1-2007 Performance Rating Method.

Based on modelling and simulations the Siemens building’s annual energy consumption is**109.5kWh/m²** (AECOM, design notes).

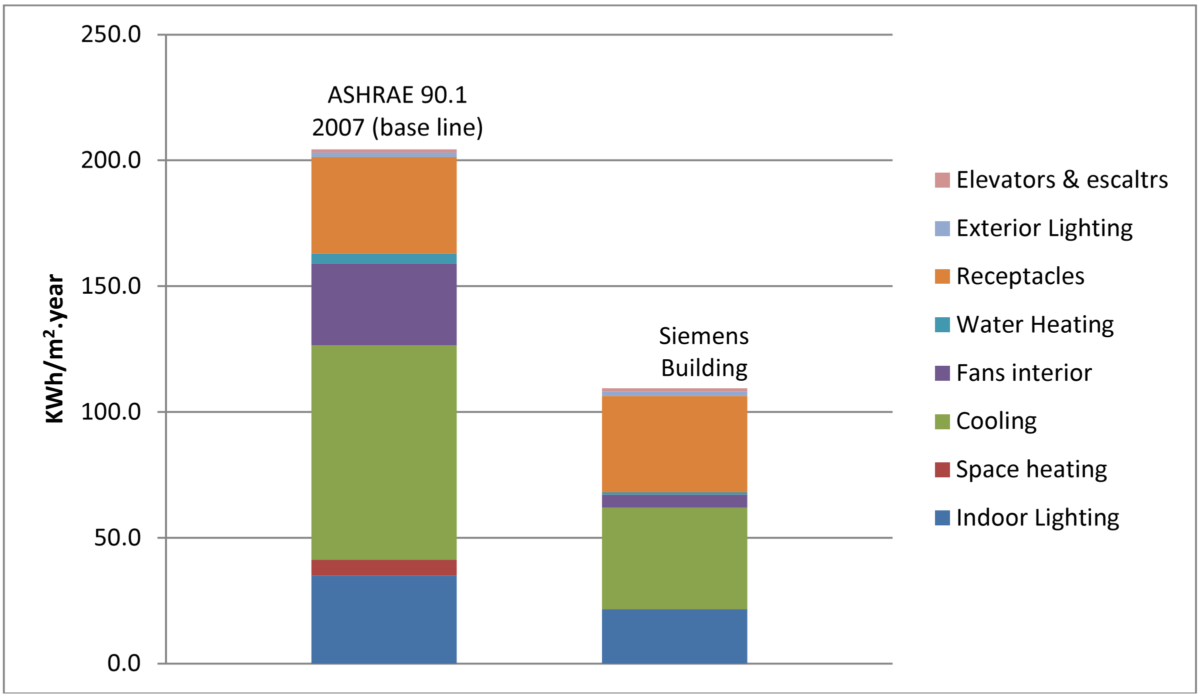

Figure 12. Annual Electricity Consumption of Siemens building compared to the baseline of ASHRAE 90.1 2007 using IES modeling software.

A breakdown of the energy use index for both the Siemens building and the baseline building that is defined by ASHRAE 90.1 2007 appendix G is shown in Figure 15. The total annual energy savings potential accounts for 2,291MWh compared to the ASHRAE baseline. Figure 15 also shows that the highest level of improvement compared the ASHRAE baseline occurs on interior fans, resulting for more than 80% energy saving. Water heating follows with 77% and cooling load –consisting of space cooling, heat rejection and pumps- comes third with 53% energy reduction.

4. Conclusions

The Siemens building is set to become a benchmark for high energy performance buildings in the Middle East and beyond, due to the energy efficiency standards, cost effective analysis and development methodology that was used throughout all the phases of the project. The design process was driven by the objective for a high performance building, maximizing environmental, commercial and social benefits.

By adopting passive design strategies that responds to the climatic conditions whenever possible, by optimizing the efficiency of all systems incorporated within the design and using an appropriate level of technology that is commercially viable to further enhance building performance, the Siemens Building in Masdar City has become one of the most energy efficient buildings in the Middle East. The contribution of extensive energy modeling throughout all stages of the design was undoubtedly essential in order the different systems to be assessed and the performance of the proposed building to be evaluated.

The main key design strategies that were adopted to achieve the high-energy performance of the building are summarized in the following bullets:

- Shaded and naturally ventilated outdoor spaces, increasing human comfort outdoors.
- Optimized Window-to-wall ratio (WWR), maximizing views and natural daylight while minimizing cooling and artificial lighting demand.
- Well insulated and airtight envelope.
- High performance glazing minimizing heat transfer and solar heat gain while maximizing daylight and views.
- External shading system providing maximum

shading on all glazed areaswhile maintaining adequate views and minimizing cleaning & maintenance efforts.

- High albedo roof coating, in order to further reduce cooling needs.
- Fan coil units with EC/DC motors and low specific fan power.
- Ventilation system including total energy recovery and passive dehumidification.
- Low lighting power density and advanced lighting controls.
- Solar collectors for domestic water heating.
- Advanced energy management system.

This study recognizes that it is concentrating on the environmental pillar of sustainability while drawing support from the other two pillars: economic sustainability and social sustainability. The common denominator of the impact from the other two pillars on the energy performance of the building is time.

The economic decisions which drove the energy solutions are based on a snapshot in time and therefore the decisions are relevant for that point in time only and it cannot be assumed that the decisions will be correct at any other point in time in the future. They may work to the advantage or just as equally likely they may work to the disadvantage of the energy performance when factoring in the overall cost impacts. Costs of different technologies will vary in time as each competes in a market that is drawing an increasing number of participants.

The social dimension is related to the behavior of the tenants and the entities that govern the tenants, both directly and indirectly, over a period of time. How the tenants use the building may vary considerably from the assumptions made in the energy modeling. Although substantial analysis of the Siemens Building design has been conducted, further research and on-going assessment is required. As the building enters into its operational phase and witnesses the desired levels of occupancy and activities, the designed performances assumptions will be rigorously tested against the detailed actual performance data taken from the advanced sub metering and BMS to allow for a factual assessment of the buildings energy efficiency levels in operation, thus allowing greater understanding of the actual implications of the design principles adopted within this landmark building whilst significantly adding to the pool knowledge within high performance buildings in hot and arid climates.

On a final note, it must be recognized that the role of the building owner is pivotal in realizing a high performance building. In this case Masdar City, as the building owner, had set the foundations for a high performance building by providing significant input prior to the start of the design of the building. This included determining the goals of the project, setting out a detailed brief, calculating the maximum construction budget, assembling the right team and setting up an integrated design process. Together these inputs had set the scene for a holistic, integrated and collaborative process which had transformed an energy idea into reality.

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المباني عالية الأداء في المناطق الحارة والجافة: دراسة حالة لمبنى شركة سيمنس في مدينة مصدر

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ملخص البحث. هناك سمات رئيسية مشتركة في المناطق الحارة والجافة وهي ارتفاع نسبة أشعة الشمس ودرجات الحرارة المحيطة بالإضافة إلى مستويات هطول الأمطار المنخفضة. وإذا ما تم تصميم المباني في هذه المناطق بالشكل الصحيح ووفقاً لاستجابتها الصحيحة للمناخ فإن هذه المباني سيكون لديها القدرة على توفير عناصر الراحة من الداخل وفي ذات الوقت التقليل بشكل كبير من استهلاك الطاقة، حيث أن قرابة الـ ٦٠ ٪ من استهلاك الطاقة ناتج عن استخدام التكييف. يجري حالياً بناء مدينة مصدر، التجمع السكني المستدام في إمارة أبو ظبي، عاصمة دولة الإمارات العربية المتحدة. وقد شهدت المدينة مؤخراً تدشين مبنى شركة سيمنس الذي تم تصميمه بحيث تنخفض نسبة استهلاك الطاقة به لـ ٤٦٪مقارنة معم عيار (ASHRAE 90.1 2007)، من خلال تصميمه الذي تم على مبدأ "صندوق داخل صندوق"، بدرجة عالية من العزل الحراري، وأنظمة التكييف والتهوية والإضاءة ذات الكفاءة العالية. ومن ميزات هذا المبنى الاستثنائية تصنيع المظلة الخارجية من معدن الألمنيوم خفيف الوزن، ليحد من اكتساب الحرارة من أشعة الشمس، مع توفير أكبر قدر من الضوء الخارجي الطبيعي والإطلالات الجميلة وغيرها من الاستراتيجيات التي تضم التصميم الذكي والفعال على حد سواء، مع الحفاظ على التكاليف على قدم المساواة مع المباني الأخرى المماثلة في المنطقة. وقد حصل هذا المبنى مؤخراً على شهادة الريادة في الطاقة والتصميم البيئي LEED من الفئة البلاتينية، مما جعله أول مبنى يحصل على هذه الشهادة في أبوظبي؛ ويسعى المبنى كذلك للحصول على درجة "٣ لآلئ" ضمن درجات تقييم المباني بنظام اللؤلؤ لـ"استدامة" الذي يديره مجلس أبوظبي للتخطيط العمراني. وتهدف هذه المقالة إلى تقديم ومناقشة جميع السمات الرئيسية للمشروع، منذ بدايته ولغاية تنفيذه، حيث ساهمت تلك السمات في تأمين كفاءة عالية للطاقة في المبنى. وسوف نسلط الضوء بكل وضوح على جميع التحديات التي تعكس الظروف المناخية الخاصة في هذه المنطقة الحارة والقاحلة.

الكلمات المفتاحية. المناخ الحار والجاف، المباني عالية الكفاءة، التصميم الذكي، كفاءة الطاقة، ومدينة مصدر– مبنى سيمنس.