

# The Masdar Development –Climate engineering for a carbon-neutral city

*The role of Transsolar in the design team for the masterplanning phase of the world's first carbon-neutral city.*

**Client:** Abu Dhabi Future Energy Company  
**Area:** 6.5 km<sup>2</sup>  
**Architect:** Foster & Partner London, UK  
**Infrastructure:** WSP Group plc, London, UK  
**Renewable Energies:** ETA - Renewable Energies, Florence, Italy  
**Transportation Consultants:** Systematica, Milano, Italy  
**Climate Engineers:** Transsolar Energietechnik GmbH



## Introduction

In 1998, WWF began its Living Planet Reports showing the state of the natural world and the impact of human activity upon it. The 2006 edition of the report confirms that we are using the planet's resources faster than they can be renewed – the latest data available (for 2003) indicate that humanity's Ecological Footprint has more than tripled since 1961. Our footprint now exceeds the world's ability to regenerate by about 25 percent. The other index in the report, the Living Planet Index, shows a rapid and continuing loss of biodiversity – populations of vertebrate species have declined by about one third since 1970. The message is clear: we have been exceeding the Earth's ability to support our lifestyles and we need to stop. If we do not, we risk irreversible damage. The biggest contributor to our footprint is the way in which we generate and use energy. The Living Planet Report indicates that our reliance on fossil fuels to meet our energy needs continues to grow and that greenhouse gas emissions now make up almost half of our global footprint. A significant part of this global footprint is used by the buildings we live and work in: about 40 percent of the world's energy is used for heating, cooling, and lighting buildings.

As with the growing worldwide recognition of the impacts of this energy use, Transsolar's views of its own role has grown, too. More than 15 years after Transsolar was founded, our purpose of climate engineering for buildings has changed from a focus on passive strategies and energy efficient systems to include how these principles fit into the global context.

## Masdar City Master Plan

As member of the design team - consisting of the architects, traffic planners, infrastructure and renewable energy systems engineers and us as climate engineers - for the Masdar City Master Plan in Abu Dhabi, we developed a new and most holistic approach of defining sustainable urban development: The six square kilometer city, designed by Foster and Partner for the Abu Dhabi Future Energy Company, is eventually to house 50,000 people in accordance with WWF One Planet Living sustainability standards, which include specific targets for the city's ecological footprint. Masdar City plans to exceed the requirements of the 10 sustainability principles - zero carbon, zero waste, sustainable transport, sustainable materials, sustainable food, sustainable water, habitats and wildlife, culture and heritage, equity and fair trade, and health and happiness.

Independent and public verification of Masdar City's performance in meeting these standards is just one of the features distinguishing the project. Another is the commitment that the project will not just preserve existing regional biodiversity but enhance it. The design team developed all of these targets that are to be achieved by the time Masdar City is completed and fully functioning, in 2012.

Masdar City is intended to be one of the world leading research and development hubs for renewable energy strategies and components based on the University Masdar Institute of Science and Technology. The laboratories and light industry production facilities are to support the vision of the UAE to develop from a technology importing into a technology exporting country with focus on renewable energy technologies. This also reflects the governments approach to prepare the UAE for the era after the oil.

### **Approach: Reflecting the Local Conditions as Climate and Culture**

The first step for the climate engineer is always to analyze the environment and setting of the buildings. A close look is taken at all existing weather data, which need to be compared before use, if more than one source exists. For Masdar this led to the decision that an environmental data measurement station should be set up on the building site to collect more data for verification. Also the proximity to the airport called for quantifying noise and other pollution to be taken into account for protection measures.

It is important in a second step to study the cultural background, reflecting solutions of city planning and building designs which have developed in these areas over the past. For Masdar City the closest relating cities with a historical cityscape are Dubai and Muscat. These cities built in a similar climate show certain patterns: buildings separated only by small streets (almost pathways) and shaded courtyards, all in order to minimize solar gains in the streets.

By reviewing natural adaptations of flora and fauna in UAE, strategies of solar and sand dust protection for water collection from dew and minimized water consumption for body waste disposals were identified. We studied the historical height layering of plant growth in an oasis with mint growing below bushes and fruit trees that are shaded by date palms. We also analyzed the adaptation of the local mangroves to the increasing salinity of the Arabian Gulf.

All of these analyses are the basis for the masterplan of Masdar City.

### **What does a sustainable approach for Masdar City mean?**

The urban density is one of the most important measures for the sustainable approach in Masdar City. It has the greatest impact reducing the energy demands in this hot and humid climate. All energy consumption must come from renewable sources and materials have to be recycled. Due to the limited capacities of renewable energies, like sun, wind and geothermal, the first essential step is to minimize the demands. The local natural adaptations showed us the way to reducing energy and material consumption. But a sustainable approach cannot be solved only by technical solutions, but demands rethinking lifestyles. This means a change in our daily behavior in respect of mobility, comfort expectations, water, energy and material consumption and waste production.

### **From Macro to Micro: Developing the Energy and Comfort Guidelines for the Masterplan, Building Guidelines and the Equipment using Simulation Tools**

Sunlight and air are the most important natural resources for a city. Outdoor and indoor spaces need to be illuminated and fresh air has to be provided for the citizens. Considering the local climate conditions in Abu Dhabi with high outdoor temperatures and humidity levels in summer and zenith sun positions this demands specific guidelines and recommendations.

As a base for an architectural design which could be evaluated and improved, the short project timeframe demanded to start based on generic models for streets and buildings. Using air flow evaluations by computational fluid dynamic CFD simulations using Fluent and daylight and shading analysis using a backward ray tracing method by Radiance, the generic models had been analyzed and the results had been used to direct the city design.

A similar approach was used for a first calculation of dynamic building loads, based on assumed construction types, external and internal gains and occupancies. Boundary conditions have been discussed and adjusted following team recommendations. Based on the final proposed exemplary building typologies the load calculations were updated, identifying the required adjustments in the boundary conditions to meet the possible energy production on site.

#### Fresh air without heat

The primary decision based on the CO<sub>2</sub> neutral approach for Masdar development was to ban cars with combustion engines from the inner city. This reduced the demand for ventilation in the city to simply providing fresh air and cool breezes, instead of also removing car emissions to a level people can tolerate. Even without these emissions the outdoor air quality demands a certain city ventilation, which has to consider predominant wind directions, annual temperature swings, heat island effects due to solar absorption and in-city emissions.

Starting with an isothermal air flow analysis to research the impact of air infiltration from the wind flow above the city into the street canyons, the model allowed to determine preferred street widths, length and piazza locations. To determine the micro climate above the city due to the high solar absorption of the photovoltaic roofs, a simplified calculation model of the whole street was defined. It was evaluated with and without wind in respect to the local temperature increases above the city. Based on the results of the generic models an optimal street and piazza design was found. More detailed models were used to study analysis of the dynamic behavior of a street and piazza climate in the arcade area and the rules to achieve a "cold island effect" for even lower temperatures than outside were identified. A new interpretation of the historic UAE wind tower for wind and sun protection and as a ventilation device concluded the air flow analysis.

With the proposed orientation and dimensions of the city grid the air quality demands could be met and the local climate demands optimized. In the Masdar development streets are mainly used for circulation, fresh air distribution and micro climate protection. Two green park bands through the whole city are oriented towards the sea breeze and the cool night winds. They create the necessary fresh air corridors through the large city grid.

#### Light in the shade

Being exposed to solar radiation is very important for the human body and soul. Due to the high outside light levels in Abu Dhabi in exposed locations, comfortable indoor and outdoor spaces have to be carefully sun-protected, but not totally darkened. The design guideline for the sizing of facade openings have to be adjusted respecting the high level of direct radiation on the project site.

In a first step the solar exposure and illumination of street locations for different street width were analyzed with the help of sun path diagrams and shading analysis. Using the generic building model, the impact of street or courtyard width, building level and glass facade ratios have been calculated and finally extended to a full matrix as a design support for the typology design development. Finally, the analysis for extreme conditions for direct sun exposure in the streets concluded the evaluations.

Based on the evaluations the project team decided to illuminate the buildings through the courtyards and not via openings to the streets. Therefore the streets can be narrow and a better thermal comfort can more easily be achieved. The courtyard design differs depending on the type of building usage. All courtyards need either a retractable shading – to protect this microclimate from high temperatures – or at least an external shading of each facade opening. Facade ratios have been determined for the different floor levels based on the final typology design.

#### Building loads in the city

The city design determines the city climate and city heat or cold island effect, which are important boundary conditions for the building loads. These depend on the building design and construction, the external loads and the internal loads which are determined by the use. Therefore each building type required a separate model, reflecting internal schedules and the hourly weather data for Abu Dhabi. Using the simulation package TRNSYS and the generic building model annual hourly loads for air conditioning and electrical demands could be identified. Adjusted boundary conditions and the final typology design resulted in three iterations. The results of the total loads and the differentiation between sensible, latent and electrical loads and their hourly daily profiles have been important inputs for the central system discussions and the sizing of the infrastructure.

A fourth iteration was necessary because of new constraints concerning the energy production on site. As a result new boundary conditions for building construction and building outfit were developed and consumer guidelines were determined in order to fulfill reduce the energy demand to match it with the limited sources.

### **Boundaries: 80% Demand Reduction**

In a global evaluation solar energy is the way to go for Abu Dhabi, using an energy and heat source which keeps the global balance of our atmosphere and is not adding additional heat. The idea of the Masdar Development for a carbon neutral city as a concept, which can be spread around the globe, demands an applicability for any other location. Even when other locations have annual solar irradiation potentials of only 1,000 kWh/m<sup>2</sup>a, the energy concept and the solutions of the storage and distribution problems in the Masdar Development can be applied but have to be transferred with local adjustments.

The limitations of the energy production areas on the roofs combined with the decision to develop the small square as well necessitated reduction of the energy consumption even further. Compared to today's UAE standards, a reduction of 80% needs to be achieved. This has serious consequences for each different building typology, as office, laboratories, housing, retail, light industry etc. These boundary conditions are not only related to the building construction but also to the building equipment and outfit. Without their compliance, the targeted numbers cannot and will not be reached.

The three following steps will lead towards a sustainable development with a carbon neutral operation: The first step is a load reduction through passive design strategies which will reduce primary energy consumption by 40% compared to today Abu Dhabi references. The second step is to optimize the supply systems and the energy demand strategies, which will allow a further saving of 30% to 40%. Finally, renewable energy sources and active renewable strategies will reduce the primary energy demand by the remaining 20 - 30%.

### **Conclusion**

Our involvement in the Masdar City masterplan project has given us the chance to view the possibilities of our work differently. Up to this point, we saw ourselves as experts in planning highly comfortable environments for the building user with a minimized energy demand. Through our work in the design team for Masdar City we were challenged to set the highest targets possible for energy savings and comfort protection in a city, enabling the team to plan a self-sufficient sustainable city – by realizing high density living and working space, which will still allow a modern but responsible lifestyle. If this can be showcased this will have global impact. Some of the key concepts of Masdar City are very innovative and have never been built in such a large scale. They demand further development and adjustment. To plan and realize these concepts in 7 years will be a great challenge.

The high standard living society in the world is responsible for the tripling of our ecological footprint. To prevent irreversible damage, we not only need to see our personal life style and its impact in a global context but also the chances that lie in our work and in the way we work. We see the vision of the Masdar Development for a carbon neutral city as a concept demanding replication in other location around the globe.