Sustainable Urbanism in Abu Dhabi

John P. Madden

This essay presents an overview of Abu Dhabi's efforts towards achieving improved levels of sustainability and high quality urbanism as a rapidly developing city through an integrated design approach. The formulation of the urban structure framework Plan 2030 with supporting regulations, guidelines and policies have been instrumental in shaping large- scale private and government led masterplans. The essay focuses on two key strategic projects - the Capital District as the embodiment of sustainable mixed use development primarily intended to house national government and commercial uses and the Masdar development as an ambitious effort to create a carbon neutral and zero waste development. The essay concludes with a summary of the lessons that can be drawn for other emerging developing cities.

Introduction

As one of the fastest growing emerging economies in the developing world, Abu Dhabi has been presented with unique challenges and opportunities from a spatial planning perspective. Abu Dhabi forms the capital city of the United Arab Emirates and sits approximately 24 degrees north of the equator in the north eastern part of the Arabian Peninsula. Over the past five years, Abu Dhabi has witnessed strong economic development, with a growth rate averaging 9 percent per year (UPC Real Estate Forecast Study, January 2010). Much of Abu Dhabi's historic growth has been linked to the exploitation of oil as it holds approximately 10 percent of the world's oil reserves and approximately 3 percent of the world's gas reserves. While its economy and resulting urban form have largely been driven and influenced by the fossil fuel era, the government's future agenda is focused on sustainability and transforming the capital city through the visionary Plan Abu Dhabi 2030 Urban Structure Framework Plan (Plan 2030). The growth of the city is expected to be largely driven by the Economic Vision Plan 2030 which seeks diversification into new sectors including education, finance, tourism, real estate, aerospace and industry with an emphasis on renewable energy. Unlike Dubai, its neighbour 90 kilometres up the coast, the emphasis has not been focused on the tallest, the biggest, the first, or the most expensive, but rather about getting back to the basics of defining the ingredients that make a great city. In the past two and half years Abu Dhabi has managed to formulate new plans, policies, and regulations to guide its own physical growth and that of its surrounding Emirate. In 2007, in order to help guide

the implementation of those plans, the government of Abu Dhabi created the Urban Planning Council consisting of an interdisciplinary team of experts to govern and regulate private development as well as work with related government agencies to align policies, processes and regulations to achieve the vision of Plan 2030. This paper will highlight the approach and process in formulating its strategic planning efforts with an emphasis on sustainable urbanism and highlight how those efforts have manifested themselves in two strategic government projects: the Capital District and Masdar.

Governance Structure and Regulatory Framework to Implement Plan 2030

Years prior to the establishment of the Urban Planning Council in September 2007, decisions concerning development in the Emirate and city of Abu Dhabi were made directly by the Crown Prince through discussions with his advisors and proponents of major development proposals. The existing Abu Dhabi Comprehensive Plan (ADCP), formulated in the late 1980's began to lack the ability to address the scale, scope or complexity of current proposed and ongoing development. Major proposals were assessed on an individual basis using a plan whose conceptual limits, scope and mandate were becoming obsolete under unprecedented developmental pressure. Added to this, the year 2005 marked a surge in developmental growth when a governmental policy change allowed foreign property investment within Abu Dhabi, putting immense pressure on the existing Plan.

Figure 1: Expert Planners during the Plan 2030 Charette

The vision of His Highness Sheikh Mohamed Bin Zayed Al Nahyan, Crown Prince of Abu Dhabi and Chairman of the Abu Dhabi Executive Council, understood the importance of undertaking a more rational and systematic approach to planning. His advisors identified global experts in the field of urban design, planning, transportation and sustainability to undertake the ambitious job of establishing a planning framework to guide the growth of the Emirate in a more systematic and sustainable way.

The plan horizon was targeted to the year 2030 and would accommodate Abu Dhabi's population growth to increase from approximately 1 million to over 3 million people but had flexibility to accommodate up to 5 million people if needed. Plan Abu Dhabi 2030 was based on a set of overarching principles. These were formulated through an iterative charrette process which gathered local and international experts to collect data, conduct surveys, consult with stakeholders not only to understand the values of those that lived, worked and visited Abu Dhabi but also to understand some of the key environmental, social and physical assets that were to be protected and responded to through the planning process.

The creation of these principles provided a foundation to help guide the formulation of Plan 2030 and are now used to guide future policies and area plans. The overarching principles that helped guide Plan Abu Dhabi 2030 are:

- Abu Dhabi will be a contemporary expression of an Arab City, which has people living, working and recreating in healthy supportive proximity to each other;
- Abu Dhabi will continue its practice of measured growth reflecting a sustainable economy rather than uncontrolled growth;
- Abu Dhabi will respect, be scaled to, and shaped by the natural environment of sensitive coastal and desert ecologies;
- Abu Dhabi will manifest its role and stature as a capital city;
- Abu Dhabi's urban fabric and community infrastructure will enable the values, social arrangements, culture, and mores of this Arab community.

Formulating Abu Dhabi Plan 2030: An Integrative and Strategic Approach

Looking back at the creation of Abu Dhabi Plan 2030, a fundamental effort was made to understand the region's positive attributes and embrace them as central to the Plan's underlying principles. Preservation, enhancement, and stewardship of the natural environment were of key importance. An emphasis was placed on the protection and

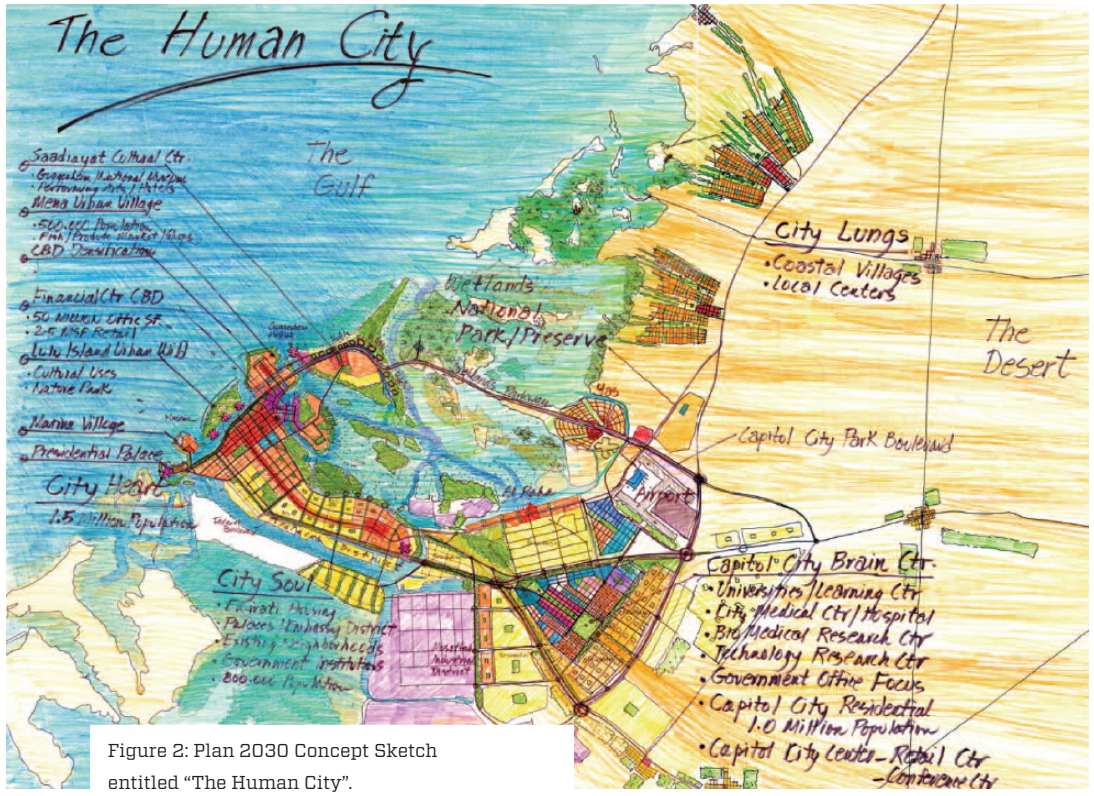


Figure 2: Plan 2030 Concept Sketch entitled “The Human City”.

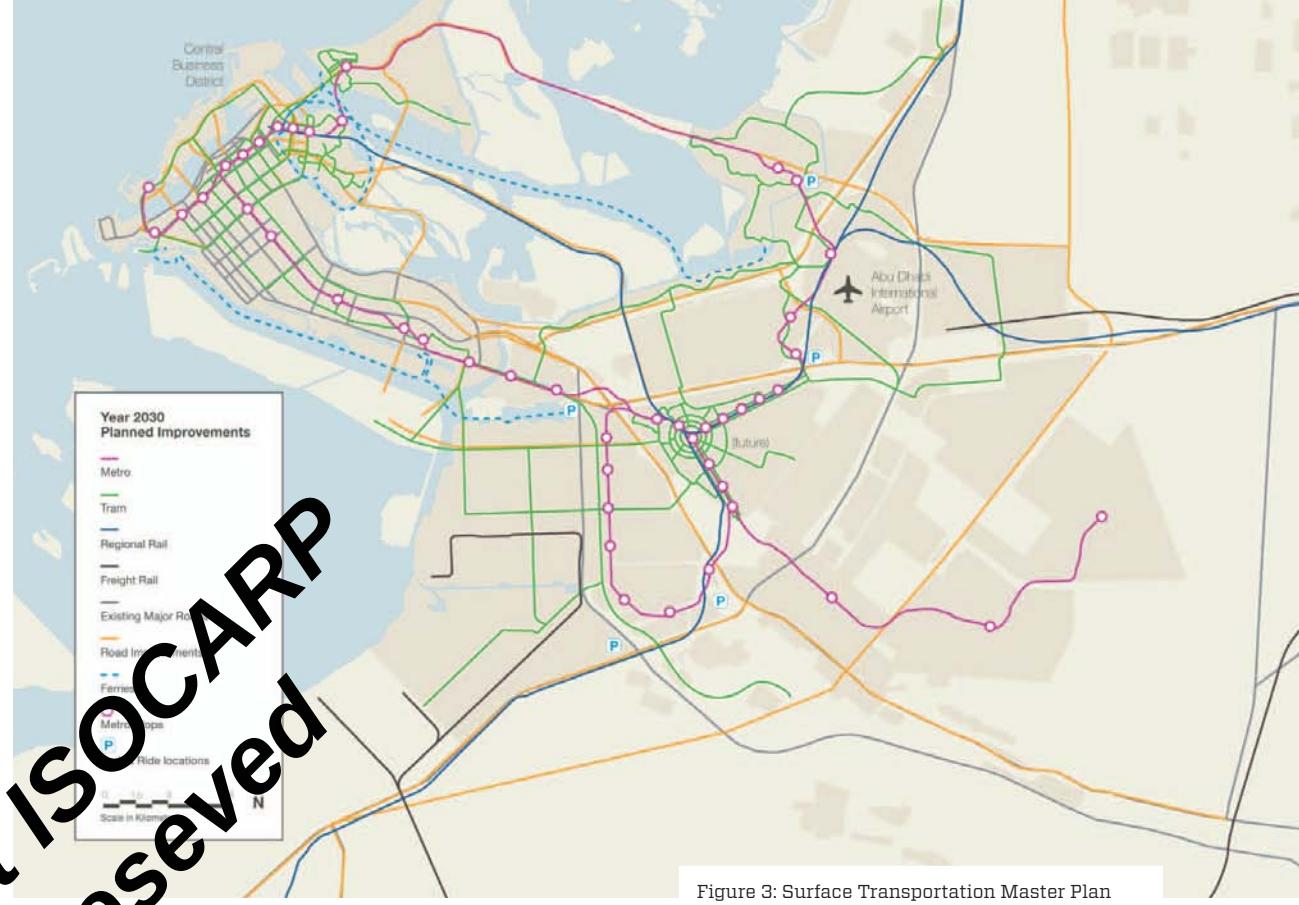


Figure 3: Surface Transportation Master Plan

enhancement of the sensitive coastal and desert environments which still give Abu Dhabi its unique identity today.

The formulation of Abu Dhabi Plan 2030 was achieved by creating a series of maps and diagrams which identified environmentally sensitive areas, natural habitats, mangroves, cultural landscapes and historic buildings, transportation networks, land use patterns, built form (height) and figure ground diagrams, open space and park systems. These maps were used to provide a diagnostic on the existing conditions and to understand where future growth could be accommodated without threatening the natural ecology, cultural and historic assets. Economic forecasts were undertaken based on Economic Vision 2030 and equated these growth forecasts for each sector of the economy (leisure and tourism, retail, administration and management, manufacturing, light and heavy industry, etc) and derived a gross floor area projection to accommodate growth in each of those economic sectors to a planning horizon of 2030. The next step was to allocate a spatial and built form dimension to those gross floor areas and to map out a series of framework and basic structure plans for land use, transportation, environment, open space, parks, built form and density. Conceptual plans and schemes were formulated for key areas including the proposed expansion of the central business district, Capital District, Grand Mosque District and Lulu Island. To help articulate the principles of the plan, a series of more detailed studies were sketched illustrating potential designs for emirate neighbourhoods, revitalization of downtown blocks and new eco villages in selected desert and coastal areas.

Transportation Framework

In order to facilitate significant growth in Abu Dhabi, major emphasis has been given to the creation of a multi-modal transportation framework to guide transportation investments that serve land use patterns and densities outlined in the plan. The underlying premise of the plan starts by acknowledging that “the best transportation plan is a good land use plan” (Plan Abu Dhabi 2030). Coupled with a good land use plan, the transportation framework envisions a fine grained and integrated transport network that will provide regular and reliable service as a viable alternative to the private automobile. In the higher density urban areas, the plan aims to ensure that transit services are located within 300 metres to where people live or work. The layered network of transit services when built is estimated to carry 30 to 40% of the peak period volume of passenger trips. (STMP, June 2009).

The existing urban structure of Abu Dhabi is based on a super-grid of arterial streets and boulevards creating mega-blocks that can stretch almost a kilometer in length. The UPC has initiated a comprehensive planning effort to create a more regularized pattern of streets to maximize connectivity and improved mobility for all modes of transportation. A finer network of streets will allow for a better distribution of traffic while creating a more robust transportation system. If one segment of the system fails there are options for traffic to take alternative routes. The most important principle for the design of the street network is to maximize connectivity, providing the largest number of smaller options rather than the smallest amount of large options. The thrust of the framework moves away from the extension of highways into the downtown toward more

human-scaled streets that are designed to move people rather than engineered to move vehicles. Expanding highways into the urban areas only serves to blight large swathes of land, devalue property, sever connectivity, increase latent demand to drive and create barriers to pedestrians.

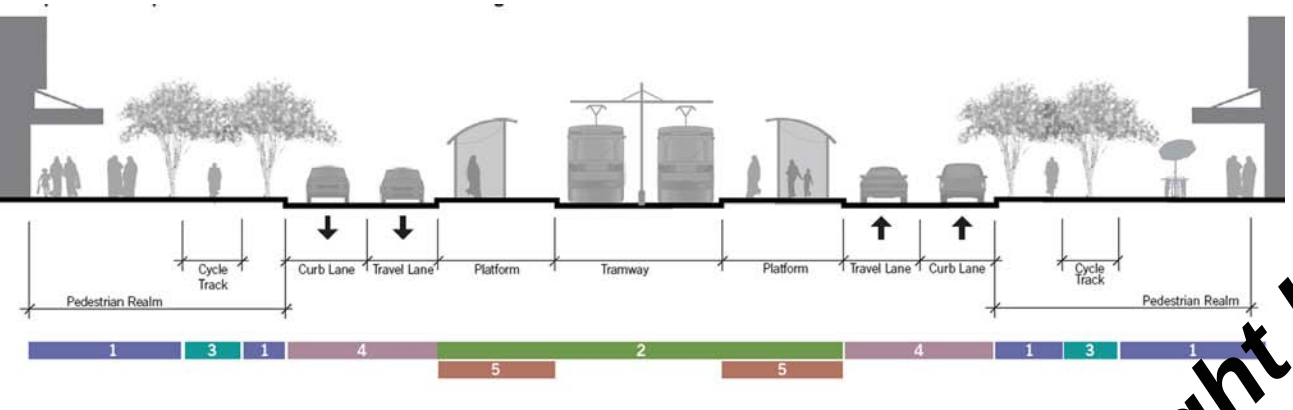


Figure 4: The Function of the Public Realm, Urban Street Design Manual.

To support this aim, the UPC has recently created an alternative urban street design manual that provides a hierarchy of street designs which responds more sensitively to land use context. The new street design manual responds to the types of activities and uses that are planned in the public realm as well as by capacity that is required to serve planned land use and density.

These principles are evident in the emerging revitalization plan for the inner city of Abu Dhabi called Wasat Al Madina, meaning the centre of the city. Connectivity is enhanced within the mega-blocks by connecting dead-end streets, and re-aligning streets to connect across blocks. This allows traffic to be distributed across a finer grid and reduces vehicle travel distance by increasing access.

As all trips begin and end as a pedestrian, plans place significant emphasis on improving the safety and comfort of pedestrians. This includes plans for constructing direct and universally accessible sidewalks, removing barriers, providing shading devices and providing investments in the public realm. Plans identify pedestrian priority areas with dedicated “shade-way” routes that connect between major activity nodes including transit stops.

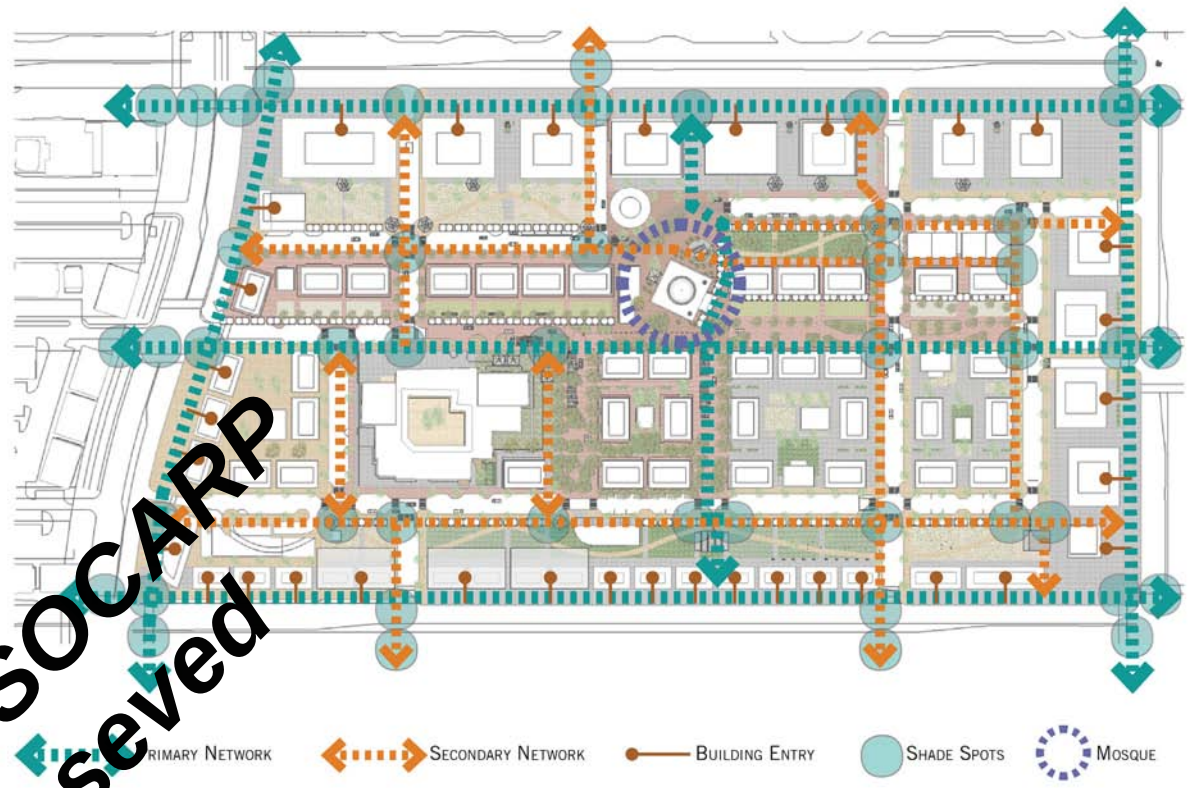


Figure 5: Identifying the Pedestrian Network, Wasat Al Madina

Land Use Framework

Rather than dispersion of growth, the plan outlines a pattern of two major growth areas: the expanded central business district on the north end of Abu Dhabi Island and the Capital District on the metropolitan mainland.

The planned expansion of the central business district will consolidate and expand the existing core to allow for the proposed financial hub to emerge on Al Sowwa Island. It will be surrounded by medium to high density mixed use and residential development to ensure it remains vibrant at all times of the day. The Capital District is the secondary core which will house government and knowledge based sectors. The two centres will be connected via a metro line which the plan envisions to extend to also connect Masdar, the international airport and eventually loop to connect Yas and Saadiyat Islands. The effect will be to improve the distribution of trips to these two centres helping to minimize congestion on Abu Dhabi Island, which is served by two bridges at the south end and the recently completed Saadiyat Bridge to the north.

The plan also defines limits to the growth of the city by creating an urban growth boundary. This is essential to preserving the sensitive ecology on the city’s edge and for preventing urban sprawl through the desert. Development limits are also defined by a system of parks and desert fingers. These effectively help to consolidate growth in a more compact footprint making it more efficient and cost effective to deliver sustainable infrastructure.

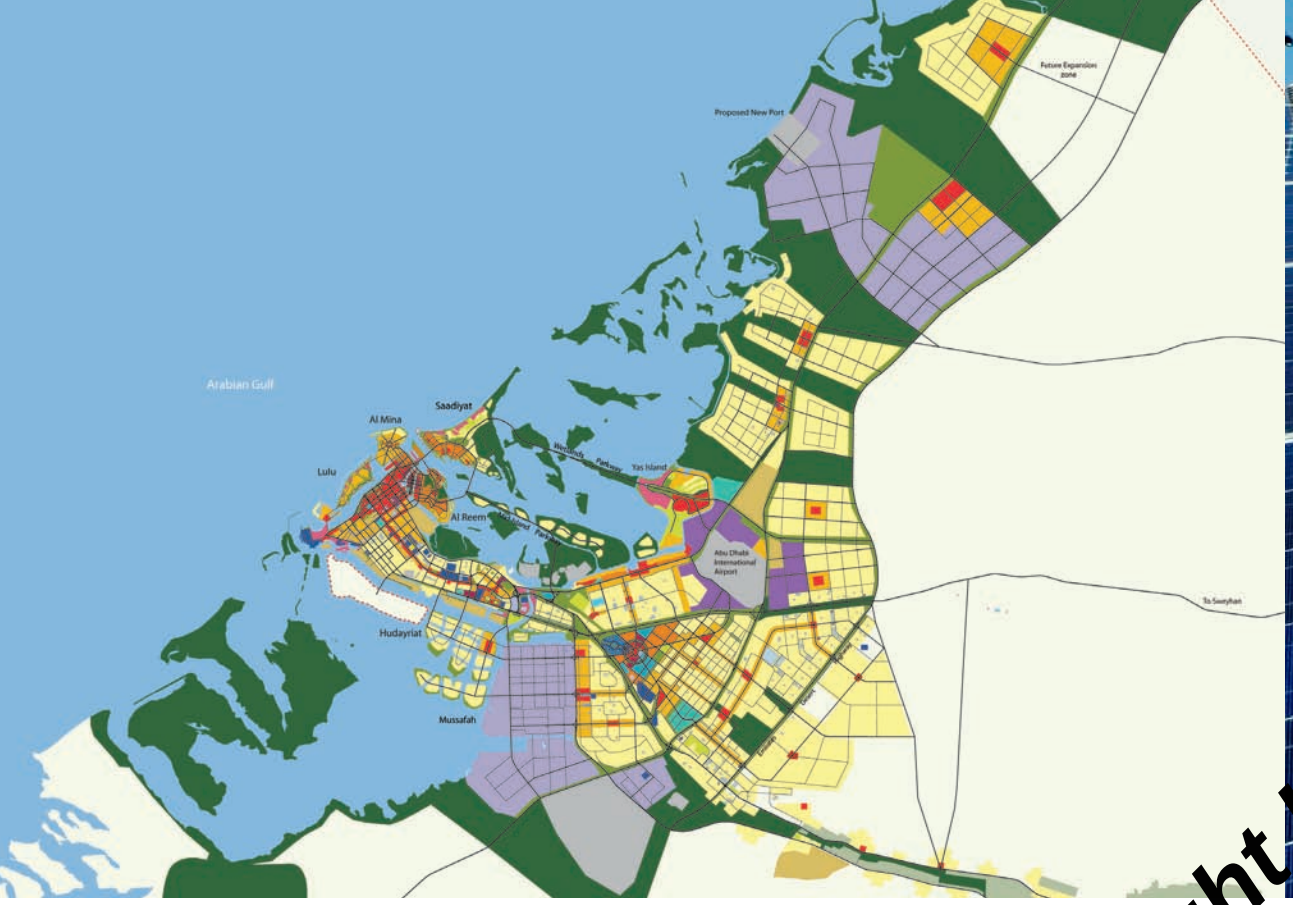


Figure 6: Land Use Framework Plan, Plan Abu Dhabi 2030

Figure 7: Photovoltaic Technologies as a Source of Alternative Energy

Sustainable Urban Infrastructure Planning

Infrastructure is a core building block to achieving sustainability. The UPC has initiated an infrastructure framework plan to address more efficient design and delivery of infrastructure to new development at a regional and building scale. The framework plan will address more efficient utilization of land for utility rights-of-way, provision of land for renewable energy production, and provision for smart grid and metering technologies. Additionally, the infrastructure plan will investigate the cost and benefits of centralized versus decentralized utility plants such as district cooling, desalination and sewage treatment to optimize the efficiency of the plants and their supporting networks.

Instead of planning large centralized systems, infrastructure components may be located closer to buildings, neighborhoods and renewable resources thereby reducing potential for network losses, inefficiencies and increased long term maintenance costs. For example, a district energy system can incorporate local energy sources such as geothermal energy or heating/cooling exchange from a water body. While large, centralized systems may be still be appropriate in many cases, an integrated approach will result in a network of more distributed and/or 'on-site' infrastructure systems, with shared elements, finely integrated into the fabric of the built environment. Visible sustainable infrastructure that residents and businesses can see contributes to awareness and more efficient behavior, and acts as a catalyst for other sustainability projects.

More efficient land utilization for infrastructure corridors through vertical stacking, combined corridors and integrated design will reduce widths of rights of way which in turn increase development potential and create more compact community footprints. Other synergies of integrated sustainable infrastructure design allow for multiple uses of space for utility corridors. For example, replacing storm water drainage pipes with landscaped swales reduces costs (less pipe and paving) while creating a green amenity which also reduces urban heat island effect.

While Abu Dhabi has approximately 10% of the world's oil reserves, it has committed to diversifying away from its economic dependence on oil by placing a greater emphasis on renewable energy. By 2020, Abu Dhabi will generate at least 7% of its energy from renewable sources (Arabian Business, 2009). Renewable energy currently accounts for a small percentage of Abu Dhabi's energy profile at less than one percent. Abu Dhabi's geography and climate gives it a competitive advantage when it comes to solar energy potential. With an average of 10 hours of sunlight / day, it has considerable potential to capture significant amounts of the sun's radiation. As part of the Masdar development initiative, a 10MW solar photovoltaic power plant has been constructed to supply some of the city's energy demands. Other alternative energy facilities are being incorporated into a newly developed Plan 2030 for Al Gharbia, located in the western region of the emirate of Abu Dhabi.

Figure 8: Establishment of a Coherent Development Review Process

The Development Review Process

The Abu Dhabi Urban Planning Council acts on two levels: first as an approval board to ensure the strategic long term development of the Emirate, and second as a guardian of Plan Abu Dhabi 2030's guiding principles. Key to achieving the plans was formulating a development review process that ensured the overarching vision of Plan 2030 would be implemented in a timely and coordinated manner.

The Crown Prince directed that a new governance body be created to manage the development process and formulate policies, area plans and regulations to guide future development in the Emirate of Abu Dhabi. In September of 2007, by Emiri Decree, the Urban Planning Council was officially launched to perform these functions. As an immediate priority, a Development Review process was established to guide development proposals to comply with the principles of Plan 2030. The Development Review process was structured on an integrative design process. Key representatives of the proponent's design team (architects, engineers, cost consultants, developer and owner) met with the development review team which consisted of the Development Planner, transportation and environmental specialist to inform applicants of key policies, guidelines and regulations that will inform the design of the master plan.

The Council's Development Review and Urban Design team now plays the lead role in reviewing and approving developments across the Emirate to ensure that new development responds to the cohesive planning frameworks for Plan 2030 in Abu Dhabi, Al Ain and Al Gharbia. As such, new development proposals within the Emirate of Abu Dhabi are subject to rigorous assessment to ensure that the approach to new development responds to its unique geographic location, context, and climate, as well as targeting market demographics in line with realistic economic projections.

Every development is assessed against how it complies with the framework plans and emerging policies. The process is set up to work in collaboration with external government agencies and utility providers so that development proposals address all the requirements in a coherent and logical way to ensure that we work towards stewarding growth that protects and enhances the unique desert and coastal environments.

The overall emphasis of the development review process is focused on two core elements: satisfaction of sustainability and urban design objectives. Key to achieving these objectives is taking a systems-based approach to designing communities more holistically rather than creating "gated islands" of development.

Estidama: A Program that Embeds Sustainability as a Way of Life

The Estidama Program was launched in May 2008 as one of the UPC's flagship programs to promote sustainable growth in the Emirate of Abu Dhabi. Estidama is the Arabic word for sustainability. Built on a 4-pillar philosophy (environmental, economic, social and cultural), Estidama is committing itself to supporting sustainable living and use of resources by working closely with communities, organizations, businesses and policy-makers to further encourage responsible decision making that moves Abu Dhabi towards global sustainability. Once fully articulated, Estidama is envisioned to touch upon every facet of daily life - the curriculum of schools, the type of investments made by the Sovereign Wealth Fund, the choice of products that companies procure, the type of food that is brought to the table and the focus on diversification of the economy to lessen its reliance on oil.

The Estidama Pearl Rating System for Communities, Buildings and Villas

Given the rapid growth that has been occurring in Abu Dhabi the initial focus of the Estidama program has been on the built environment. To that end, the Urban Planning Council created the Pearl Rating Systems (PRS) to guide all new physical development in becoming more environmentally sensitive and much more climatically responsive in its design and construction. Abu Dhabi Urban Planning Council established a clear vision for sustainability as the foundation of any new development occurring in the Emirate. More than just a sustainability program, Estidama is the symbol of an inspired vision for governance and community development.

Through implementation of the PRS it is estimated that a savings of approximately 11,000 GWh in the residential sector alone could be realized which equates to a financial savings to the

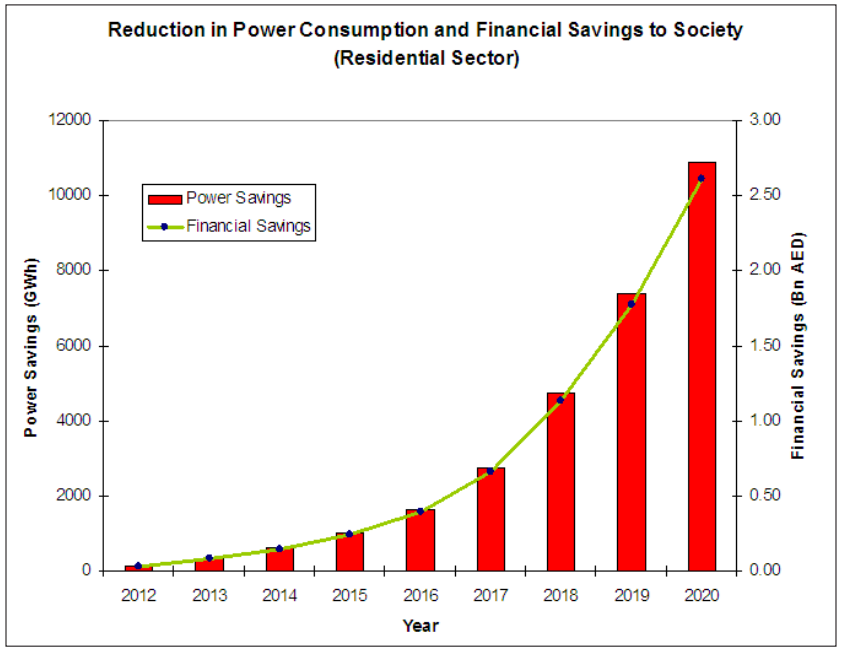
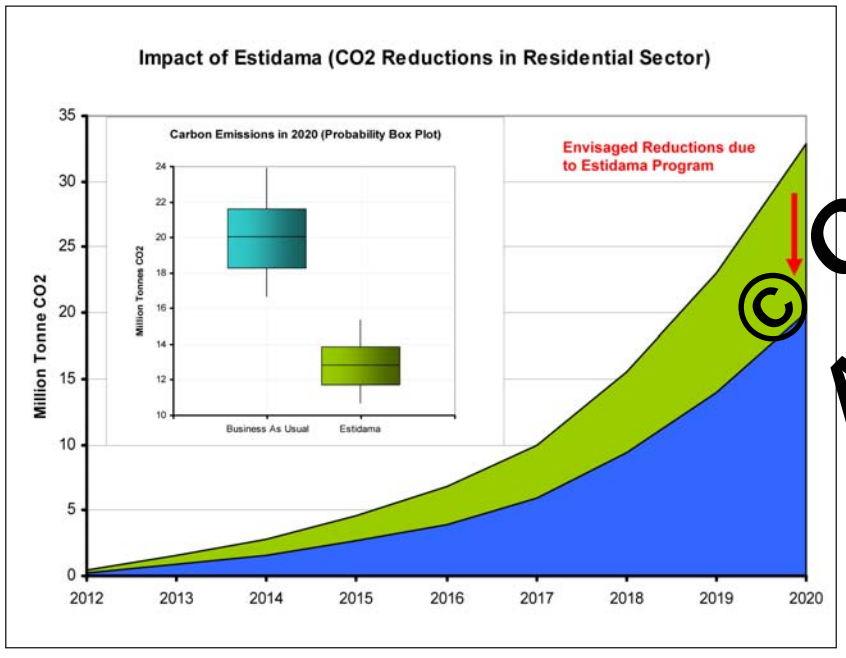


Figure 9: Reduction in Power Consumption and Financial Savings to Society (Residential Sector)

Figure 10: Impact of Estidama on CO2 Emissions Reduction in Residential Sector (2012 – 2020)



Source: Real Estate Market Forecasts, DR&UE, ADUPC; Energy and Water Savings and Pearl Rating System, ARUP; RSB Estimates for Cost of Electricity Generation; DR&UE Assumptions on Policy Penetration; US EPA eGRID for emissions from natural gas power plants in the US; Executive Affairs Authority, Abu Dhabi for maximum emissions in electricity sector factoring desalination (Consolidated number not decoupled for energy and water); DR&UE Analysis.

society in the order of AED 2.6 billion per annum at current cost (2010) of production of electricity (Figure 9). Similar outcomes would be anticipated for the commercial, retail, hotel and public sector buildings as well.

The PRS will not only result in significant operational savings for new buildings but it will also result in significant reduction in carbon emissions. With the potential energy savings that are achieved through the government mandated requirements towards energy efficiency, it is estimated that the Estidama Pearl Rating System has the potential to reduce carbon emissions by over 35 percent over a "business as usual" approach to new development over the next 10 years (Figure 10).

The Pearl Rating System takes an integrated approach by addressing sustainable design at all stages in the life of buildings and communities – planning, design, construction and operation. The UPC is one of the first planning authorities to formulate and administer a building and community rating system that addresses specific climate conditions, local culture and the regional context. The advantage is that the system is fully adapted and responds to the regulatory framework that is being developed by the UPC. At the same time, new building code and development regulations have also been developed which have enabled the alignment of multiple regulatory tools to address sustainability from buildings to large-scale master planned communities.

The Pearl Rating System is organized into seven categories that address performance and design metrics (Figure 11).

- Natural Systems: Conserving, preserving and restoring the region's critical natural environments and habitats.
- Livable Communities: Improving the quality and connectivity of outdoor and indoor spaces.
- Precious Water: Reducing water demand and encouraging efficient distribution and alternative water sources.
- Resourceful Energy: Targeting energy conservation through passive design measures, reduced demand, energy efficiency and renewable sources.
- Stewarding Materials: Ensuring consideration of the 'whole-of-life' cycle (from extraction and manufacturing to transportation, useful life, and disposal) when selecting and specifying materials.

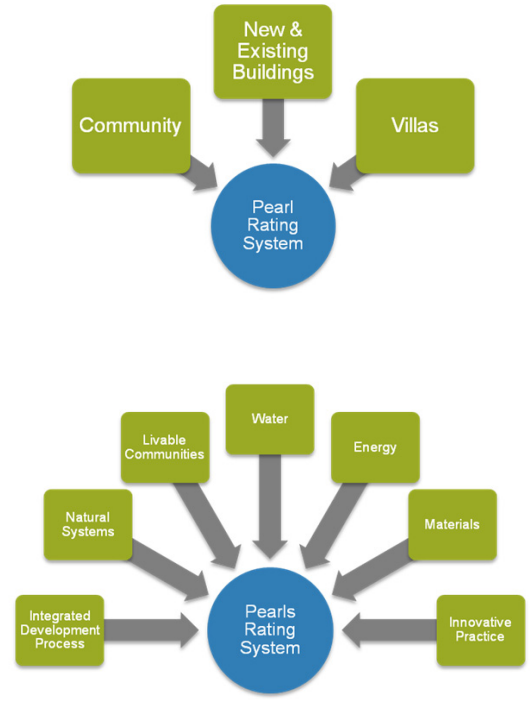


Figure 11: Performance & Design Matrix, Estidama

Each of these sections contains both mandatory and voluntary credits intended to help the design team address the 4 pillars of the Estidama program. The PRS system places greater emphasis on

the credit weighting toward water and energy efficiency. The PRS has a monitoring and enforcement aspect which is also unique to other rating methods.

Most importantly, the PRS is context sensitive and focuses on how the built environment responds to the extreme heat and humidity of a coastal desert. A core mandate of the PRS requires that passive design strategies be undertaken throughout the planning and design stages of the application process. Key strategies include the orientation of the street grid and building plots to allow penetration of prevailing northwest coastal winds through the building site. The built form can also contribute positively to the local micro environment by orientation of buildings to provide shade on the public realm and providing variations in height to help direct winds downward to the pedestrian realm without creating a wind tunnel effect. Appropriately implemented, these factors will help realize immense benefits in the livability of the built environment. Credits also encourage the use of “grey water” or treated sewage effluent (TSE) for irrigation and district cooling systems. Abu Dhabi has commissioned the construction of a treated sewage effluent (TSE) plant which will have a capacity of converting 430,000 cubic metres of sewage per day and will use processes such as ultra filtration treatment and ultra violet light disinfection (The National, July 13, 2010).

Case Study: The Capital District

The Capital District forms the gateway to Abu Dhabi and is one of the major strategic initiatives of Plan 2030. The Capital District Masterplan provides a long term vision toward 2030 for the development of a global 21st Century capital based on sound planning principles, sustainable criteria toward environmental quality and energy consumption, and a desire to provide the highest quality of life possible for all its citizens.

The plan for this forty-five square kilometre site provides for a projected population of three hundred and seventy thousand residents. The Capital District is one of the most ambitious urban development projects being planned in the United Arab Emirates. In creating this new city, the Masterplan has capitalized on the site’s physical assets - its centrality within the region and accessibility to both Abu Dhabi Island and to emerging developments on the mainland, its proximity to a well-connected highway network, coastal climate and breezes, and its adjacencies to existing residential neighbourhoods.

The site’s triangular shape provided strong cues for organizing development around proposed high capacity transit lines through the site and in creating a series of symbolic and visual axes that link important civic spaces and landmarks, terminating at a central civic space that will represent the nation.

The Capital District is planned as a sustainable, compact, mixed use city, comprised of high-density transit-oriented communities, employment, major universities, hospitals and knowledge based employment sectors, as well as a lower density Emirati neighbourhood. A central driver behind the Masterplan vision is the symbiotic relationship between land use and transportation in the creation of high quality, attractive district and neighbourhood centres, vibrant streets and public spaces, and well-planned cultural and community

Figure 12 Capital District Plan & Context

Figure 13: Transit Orientated Communities

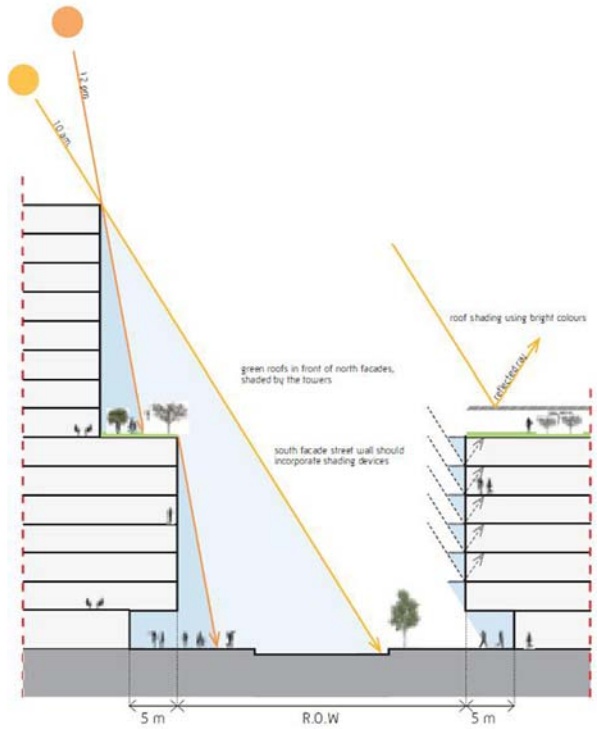


Figure 14: Solar Shading from street-wall setbacks

facilities, all served by a world-class public transportation system.

The Capital District will be the new seat of national government and house a diplomatic and embassy neighbourhood. It will also serve as the city of Abu Dhabi's second business district, providing over one hundred thousand jobs in a dynamic mixed-use urban core. In addition to a dense network of open spaces and community uses to support the local population, the Capital District will host an Olympic caliber 65,000 seat National Stadium as well as various sports venues and conference facilities. New universities and research facilities will position the city as a hub for education and research. The new city will also be a leader in environmental sustainability, with requirements for the use of highly energy efficient building structures, district cooling systems, water sensitive landscaping and irrigation and an overall urban design plan that promotes connectivity and pedestrian comfort.

Again, Abu Dhabi's desert and coast climate will pose significant challenges to maintaining human comfort in outside urban environments. The plan seeks to mitigate the negative impact of thermal heat gain through comprehensive systems of shade and ventilation throughout the urban environment.

The fundamental principles guiding the geometry of the plan seek to naturally ventilate the city by having roadways, block orientation, landscape and building form oriented to capture the prevailing winds as a cooling source. Throughout the planning process, modeled design scenarios were tested in order to understand the implications from a wind and cooling standpoint.

Based on results from these studies and additional scientific research, strategies were developed to guide decision-making with regard to the orientation of streets and the positioning and dimensioning of buildings in order to best take advantage of the wind. Also, shading devices such as arcades, trellis and landscaped canopies are planned as a complex network of places that allow pedestrian movement, solar protection and refuge from the harsh climatic conditions of Abu Dhabi.

Sustainable practices towards conservation of energy and water are key priorities of the Capital District Plan. The plan optimizes building energy use and water consumption through the application of "green building" practices as defined by the government's Estidama Program. The design of the public realm and open space systems will incorporate xeriscaping strategies which use drought resistant plantings and materials which significantly reduces the consumption of potable water. Recycling centers will be located within the ground floor of public parking facilities and encourage individuals and households to recycle.

In addition to enhancing urban fabric and community infrastructure which will enable the values, social arrangements and culture of the Emirati communities to be preserved, Capital District clearly aims to manifest Abu Dhabi's role and stature as a capital city.

Figure 15: Integration of Built Form into the Public Realm, Capital District

Figure 16: Oblique view of Masdar development proposal

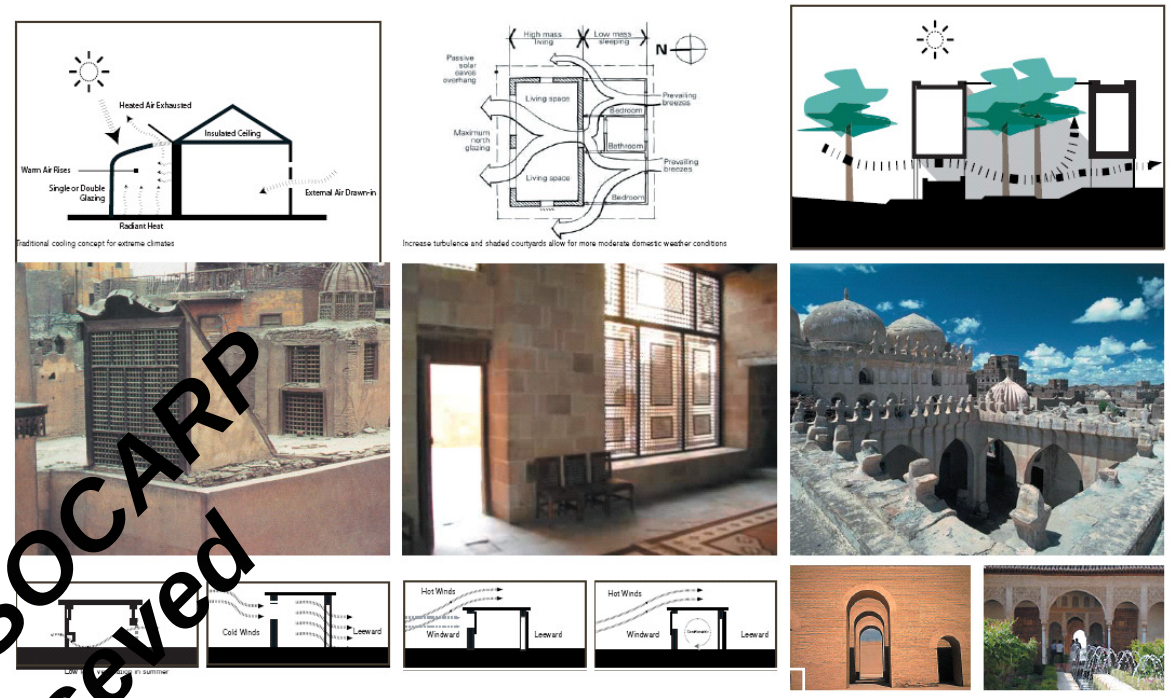


Figure 17: Traditional Passive Design Techniques in Islamic Architecture

Case Study: Masdar

Masdar is planned to be a mixed-use development strategically located on the metropolitan mainland of Abu Dhabi between the international airport, Capital District and approximately 17km from the existing central business district at the north end of Abu Dhabi Island. The plan aspires to create a carbon neutral and zero waste city which will become a model for demonstrating traditional and high tech approaches to sustainability in the region. The 640 hectare site of Masdar will accommodate 40,000 residents and approximately 50,000 employees when fully built (Masdar City Development, UPC Review Panel Report, 2008).

The focus of the development is centred on the Masdar Institute of Science and Technology (MIST) and the headquarters of the International Renewable Energy Agency (IRENA). The first phase of the development will have an academic and research focus on sustainable technologies and alternative energies. In addition to the educational facilities, the mix of land uses include commercial, community and residential uses which help to create a job-housing balance which in turn reduces the potential number of commuter trips. The planned mix of land uses will also help create a more vital community and sense of place.

The master plan for Masdar incorporates traditional Islamic-Arabic design with advanced sustainability techniques into a contemporary architectural expression. The spatial footprint of the development is very compact but is relatively low in scale with predominate building heights ranging from 4 to 7 stories. Studies have shown that the optimal densities to support a basic provision of commercial services and

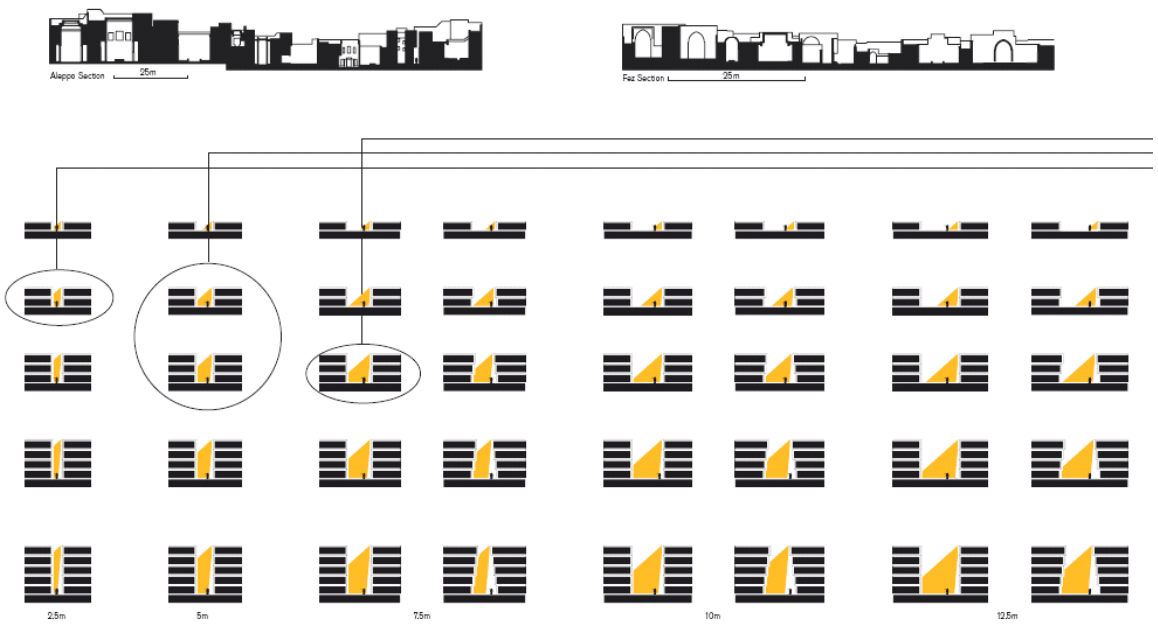


Figure 18: Solar shading analysis - street widths to building height ratios

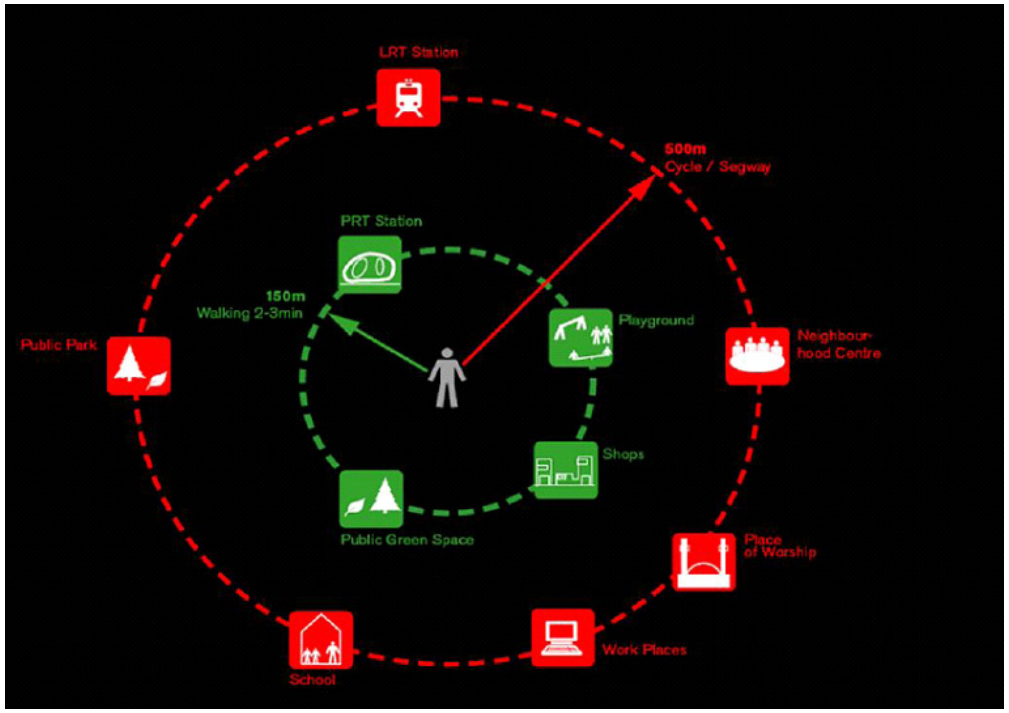


Figure 19: Transportation Strategy, Masdar

public transport is about 5000 people within a catchment area of 300 metres walking radius. This equates to a design population density of 200 people per hectare. To induce greater pedestrian trips, the Masdar plan proposes densities of 245 people per hectare, which reduces the effective pedestrian catchment areas to nearly 150 metres (Figure19).

The transportation strategy is premised entirely on alternative modes to the private automobile. All trips within the Masdar development will be either by transit, walking or cycling. To achieve this, the plan proposes a hierarchy of transit systems including a personal rapid transit system (PRT) and a network of bicycle and pedestrian routes that are seamlessly interconnected. A compact development footprint, a comprehensive alternative transportation network and strategically clustered public facilities and amenities induce a greater number of pedestrian trips. The transportation strategy alone will reduce carbon dioxide emissions by 7 percent (Masdar, 2010)

The planned orientation and layout of the development responds to climate and its geographic location. Through solar analysis and thermal dynamic modeling, the design strategy of Masdar evolved to minimize solar radiation and thermal heat gain. The entire city's street orientation and urban structure were rotated by 45 degrees to the northwest to minimize solar gain within the public realm and along building facades thereby reducing the potential cooling load of buildings and improving overall microclimate and outdoor thermal comfort. Building height to street width ratios help to maximize solar shading.

Figure 20: Pedestrian routes with passive and active solar shading

Figure 21 Grid Orientation & Built Form, Masdar

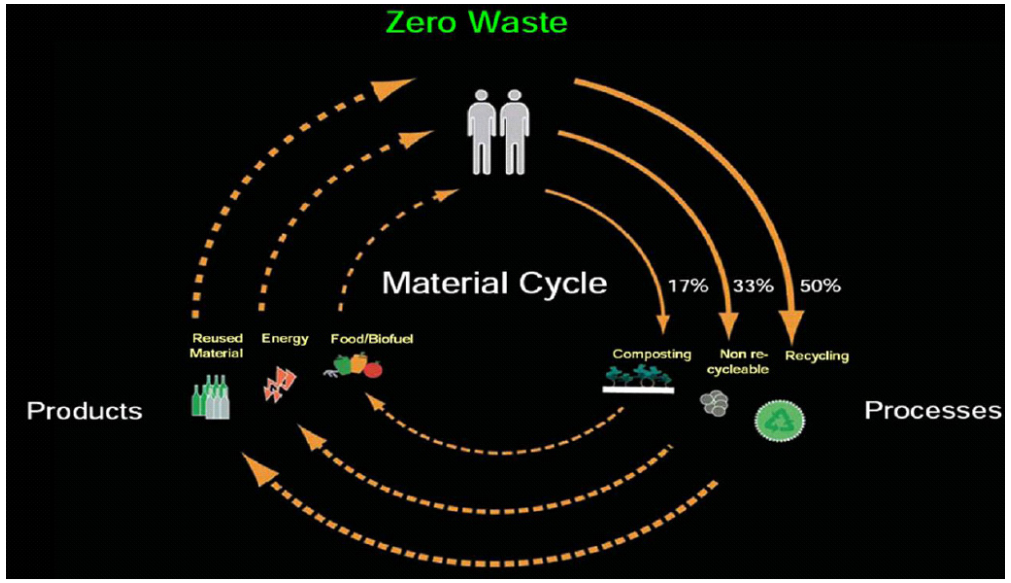


Figure 22: Zero Waste and Material Reuse Strategy

The combined passive solar strategies with the improvement in building energy efficiencies (i.e. high efficiency building envelopes, ventilation and air conditioning systems, improved shading devices, etc.) is estimated to help to reduce CO2 emissions by up to 56% (Masdar, 2010).

Masdar plans that all of the energy to be used within Masdar City will be generated through renewable sources including:

- 8 % waste to energy
- 16% evacuated tube collectors
- 36% concentrated solar power (CSP)
- 42% photovoltaic

The utilization of renewable energy is estimated to reduce carbon emissions by approximately 24% compared to "business as usual". The development of Shams 1, a100MW concentrated solar plant (CSP) in the Western Region of Abu Dhabi will contribute significantly to the renewable energy supporting the operations of the development. Apart from the CSP plant, the alternative energy generation, waste management, wind farms, bio-remediation fields and grey water recycling are almost entirely integrated within the site.

The Masdar project has also targeted the development to be zero waste. In the initial stages it has already implemented this strategy by diverting construction waste generated on site as well as using residual concrete and wood waste from surrounding construction sites to be incorporated into the initial phase of development. Scrap wood waste is converted into wood chips to place over landscaped areas and footpaths. This material helps to reduce evaporation of irrigation water in landscaped areas as well as replacing asphalt or concrete for footpaths which helps reduce embodied carbon and heat island effect. Masdar has targeted 50% of the materials that are used on site to be either reused or recycled with 33% of non-recyclable waste being converted to energy. Plans include systems for 17% of all organic materials to be composted or converted into bio-fuels (Masdar, 2010, Figure 22).

Education and awareness will be a critical component to shifting behavior to meet its sustainability targets. To help assess the success of the Masdar sustainability initiative, an intelligent metering and building control system has been planned to monitor water, energy and waste. These systems are intended to help inform and educate occupants as to how they rank against the established targets. Ongoing monitoring to assess progress will play an important role in ensuring compliance with such targets.

The Masdar plan will be integrated with regional transportation infrastructure with an emphasis on accommodating the planned metro and tram network. Further, its immediate proximity to the international airport will create an easy and efficient public transit link between Masdar and the International Airport, Capital City, Raha and the existing central business district on the north edge of Abu Dhabi Island.

Conclusion

Abu Dhabi has experienced remarkable growth and change since the discovery of oil transformed it from a small pearl fishing village into a modern metropolis. With projected growth expected to treble the city's population growth over the next quarter century, Abu Dhabi is presented with some unique challenges and opportunities. The UPC has focused its attention on the rapidly changing built environment as part of its Estidama Program and has developed plans that will help guide future growth in areas earmarked for growth based on sound sustainability principles that seek to protect the environmental assets and restore the natural systems that give Abu Dhabi its unique identity.

The most resilient cities will be those that respond to challenges through innovation. Both the Capital District and Masdar have been highlighted for their innovations in urban design, built form

to sustainable technologies which are intended to improve the overall efficiency within the city. The success of the planning efforts is also dependent on establishing strategic partners that are committed to realizing its success. This includes the development and construction industry, government agencies including transportation, and environment. Utility and infrastructure providers must be willing partners to adapt to innovative approaches to more integrated infrastructure design and delivery. Ultimately, planning must capture the minds and build the capacity of the citizens that use the city. It is not enough to build sustainable buildings and communities if the broader population is not empowered to act in a more sustainable manner.

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