MASDAR CITY

FROM VISION TO REALITY: MASDAR CITY'S JOURNEY TO NET-ZERO

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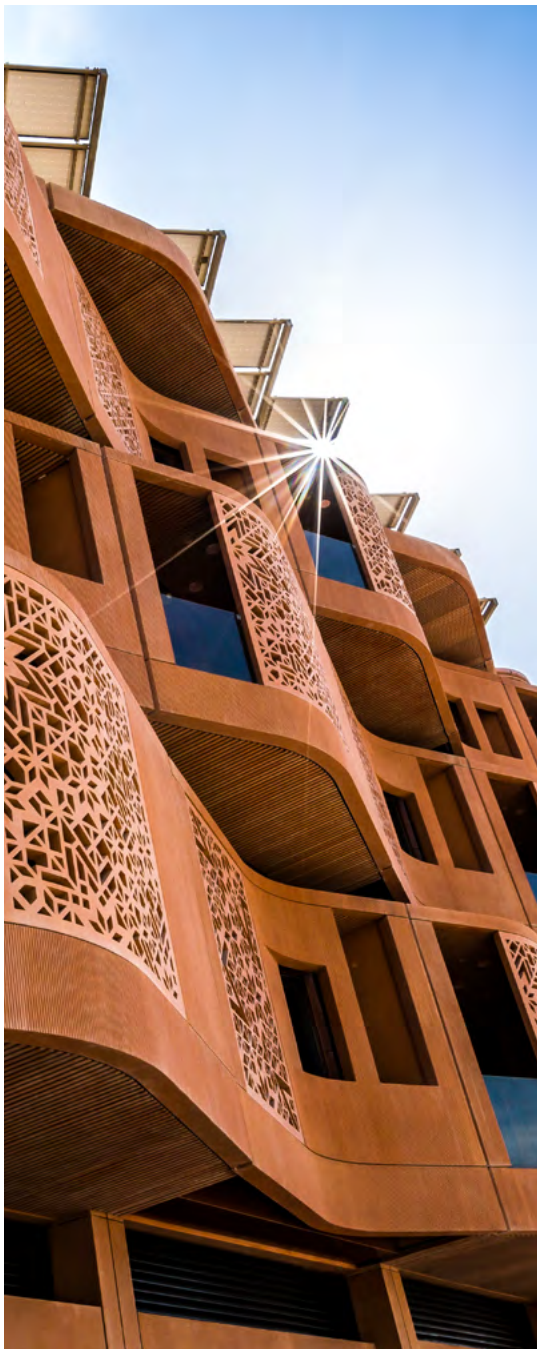
FOREWORD

Climate pledges, including promises to reach net-zero by some future date, abound in the public domain. It's evident that the climate is at risk, necessitating urgent and substantial changes. While making these commitments signals our dedication to change, we must question their feasibility. Can we move beyond merely discussing challenges and strategies to craft a viable, data-driven plan for reaching net-zero?

Cities in particular face challenges with decarbonization. They contribute substantially to carbon emissions due to factors like population density, reliance on fossil-fuel transportation, and construction activities. Yet, these challenges also present opportunities for positive transformation. Businesses have the potential to unlock new opportunities for value creation, uncover efficiencies and build resilience for the future - not only to reduce carbon emissions but because it offers economic benefits.



This paper delves into the experiences of Masdar City, a sustainable urban development in Abu Dhabi that has been pursuing net-zero for over 15 years. Changes inevitably took place, both externally and internally, as one would expect in any business environment. However, through a focus on innovation and holistic planning that integrates natural environment, passive architectural design, technology, renewable energy, and all carefully balanced, we have learned that net-zero is an attainable goal. With a focused approach, collaboration, and perseverance, this goal is emerging as a reality.

Looking into the future, we will maintain our commitment to our net zero journey. We will continue to adapt our approach to create value and build resilience in a rapidly changing environment. Moreover, we will continue sharing our insights. This white paper outlines our path towards decarbonizing our sector, presenting action plans aimed at radically enhancing the sustainability of our built environment, ensuring a low-carbon, sustainable future for our city and community.

Mohamed Al Breiki
Masdar City, Executive Director, Sustainable Development

MASDAR CITY: WHERE SOCIAL, ECONOMIC, AND ENVIRONMENTAL SUSTAINABILITY CONVERGE

Masdar City broke ground in 2008 with the goal to develop a global benchmark for sustainable cities. Initially, the plan was to develop rapidly; however, economic factors necessitated a reassessment of our strategy to ensure long-term viability.

This required a more financially prudent approach and an expanded understanding of sustainability. Beyond environmental protection, we needed to prioritize community well-being and commercial viability. Through experimenting on emphasizing different aspects of sustainability, it soon became clear that all aspects of sustainability are important and cannot be left behind. Thus, our approach to sustainability now encompasses three pillars: environmental, social, and economic.

A SHIFT: BALANCING ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY

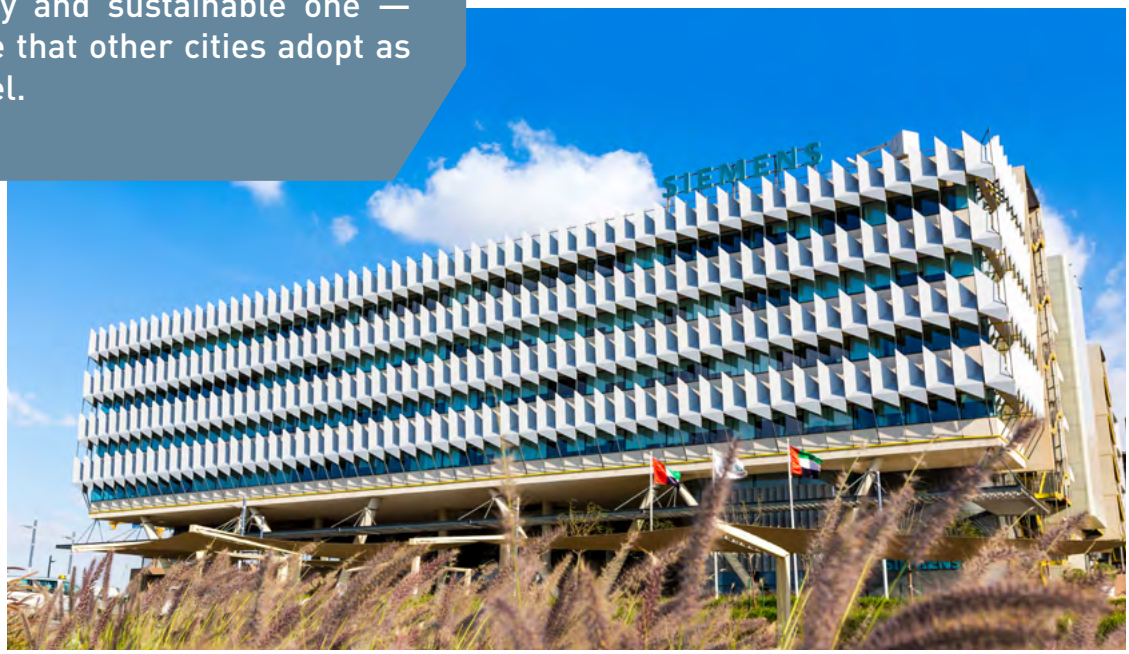
By 2010, Masdar City saw the completion of a series of buildings which was to become the home of the Mohamed bin Zayed University of Artificial Intelligence (MBZUAI). The MBZUAI excelled in environmental credentials, supported by highly insulated building envelope design and renewable energy systems on the roofs.

However, by this time the world was going through a global financial crisis. Abu Dhabi was not immune to the effect of this crisis. Under such an economic environment, a shift in the direction of Masdar City was about to take place. This shift marked a pivotal moment in Masdar City's evolution. Whereas the earlier focus was solely on environmental sustainability, the new focus was on economic sustainability in the form of commercial viability, but at the same time upholding environmental stewardship.

The first building to adopt this shift was the Middle East headquarters for Siemens. The design was initiated in 2010 and construction was completed in 2013 to become the first LEED Platinum certified building in Abu Dhabi. This landmark building demonstrated that buildings could be environmentally friendly and commercially viable at the same time.

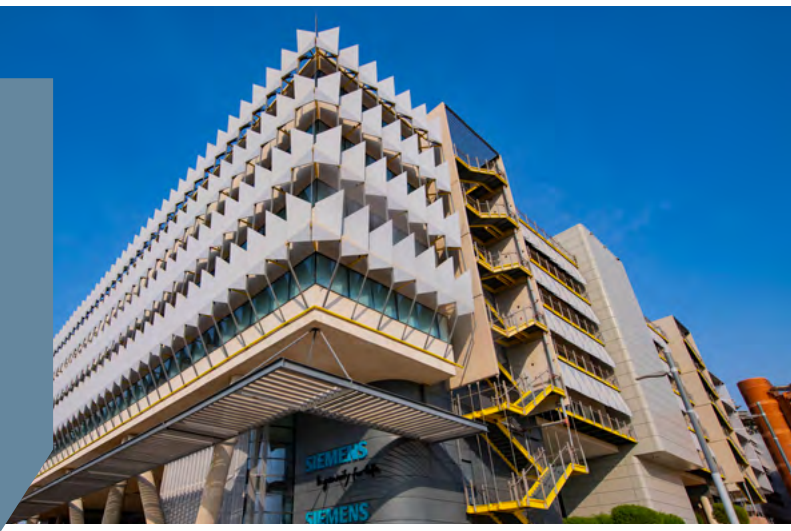
Ideas about a design approach that improved environmental and economic performance concurrently spread through the Masdar City design and development teams. There was an acceptance that the environmental credentials and economics of a building can be balanced to create a "win-win" situation. From here on, Masdar City began to define and optimize its own approach to a more sustainable future.

The Siemens building marked a new trajectory for Masdar City: Green construction without the green premium would imply a slower journey to net-zero than we had originally envisioned, but a steady and sustainable one — and one that other cities adopt as a model.



MASDAR CITY TODAY

The Siemens building was the first of many LEED Platinum buildings which followed in Masdar City. Today, the city is home to one of the largest clusters of LEED Platinum buildings in the world at 21 and counting. Two more buildings have been completed, with LEED Platinum rating pending final award: our first net-zero energy commercial building, as well as our first mosque.



Thirteen additional LEED Platinum buildings are under construction:

MC²
مجمع مدينة مصدر
MASDAR CITY SQUARE

Masdar City Square, a seven-building commercial development with an iconic net-zero energy commercial HQ, will be complete in 2025.

THE LINK

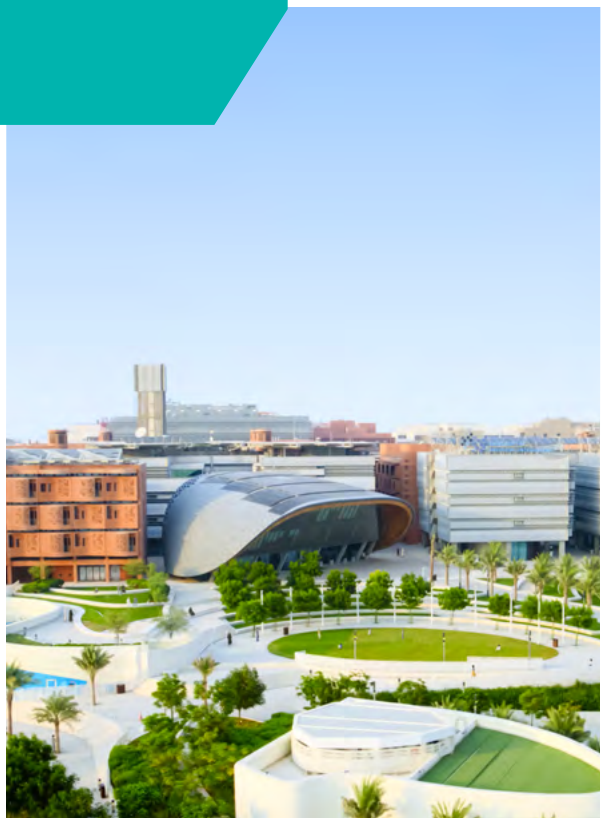
The Link, a five-building commercial and residential development that will feature the region's first net-zero energy shared working and living space, will be complete in 2025.

NET ZERO ENERGY MOSQUE

Masdar City's second mosque which will accommodate 1,300 worshipers. Due for completion in 2025.

All 13 of these buildings are also on track to receive WELL Gold and Estidama 4 Pearl certifications, with the three projects on track to achieve net-zero energy certifications from either the International Living Future Institute or U.S. Green Building Council.

A PRACTICAL METHODOLOGY FOR SUSTAINABLE URBAN DEVELOPMENT



Since its inception, Masdar City has served as a platform where we were able to develop and hone a methodology that has allowed us to pursue net-zero in a way that is practical and commercially viable. While we use our methodology within our specific context, the United Arab Emirates, the principles can be applied elsewhere in the world so that other cities can chart their own path to net-zero.

Our methodology begins with a holistic, forward-thinking brief that optimizes and balance environmental, social, and economic sustainability, it prioritizes passive design techniques and supplements them with active design, applied technologies, and renewable energy.

This is all brought together with the support of a multidisciplinary team.

CREATING THE BRIEF

Traditionally, a development project starts with an idea, which gives rise to the formulation of a brief. Given the breadth and depth of knowledge required for a sustainable development project, a comprehensive brief requires input from multiple disciplines and teams.

There are three primary parameters to consider:

CLIENT NEEDS

BUDGET

ENVIRONMENTAL CRITERIA

CLIENT NEEDS

A building that is developed to meet a client's specific needs is inherently more sustainable than an "off the shelf" building. Purpose-built buildings mean more efficient operations, less wasted space, and less retrofitting.

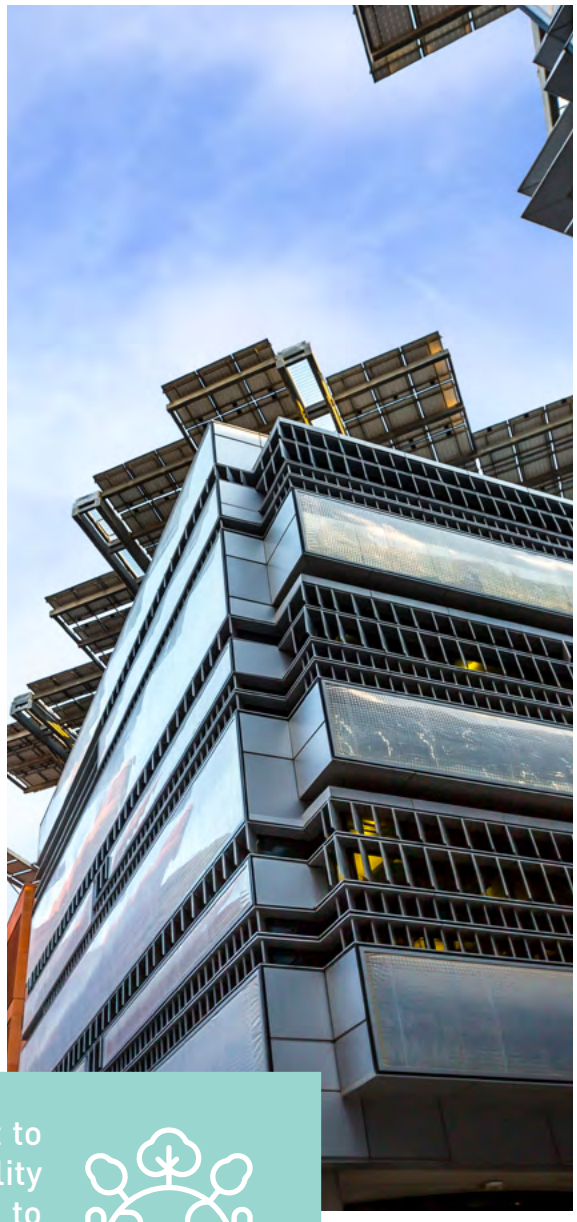
The well-being of a building's occupants is also essential. Particularly post the COVID-19 pandemic, building developers are attuned to how we experience buildings. The WELL Gold rating, which Masdar City now embraces for all new developments, is designed to help ensure buildings support the health and well-being of its occupants.

BUDGET

One of the common challenges of sustainable design is the perception that it requires a higher budget than conventional design. However, at Masdar City, we have proven that this is not necessarily the case. We have developed a methodology that allows us to achieve high levels of sustainability within reasonable and competitive budgets.

Our first demonstration of this methodology was the Siemens building, which achieved LEED Platinum certification with no additional cost compared to a standard commercial building. We accomplished this by integrating sustainability principles into the design process from the start, and by applying innovative and efficient solutions that met the project's objectives and constraints. The Siemens building remains as one of the most commercially successful buildings in Masdar City.

Some of our subsequent projects have gone beyond the Siemens building in terms of sustainability performance. These projects have involved a slight increase in the initial cost per square meter, but they have also generated higher returns in terms of rental income, operational savings, and environmental benefits. In today's market, there is a growing demand for sustainable buildings from clients who are aware of the social and economic advantages of green design. Therefore, sustainable buildings are not only feasible, but also desirable and profitable.



The key to achieving this outcome is to commit to a realistic budget and to incorporate sustainability into the plan from the very beginning. Trying to retrofit sustainability features into an existing design is much more expensive and less effective.

ENVIRONMENTAL CRITERIA

An essential factor in the brief for sustainable building design is how to treat environmental sustainability as a mandatory requirement, not as an optional add-on. It should not be compromised by budget constraints. It should be the foundation of the design process. Our vision is that "sustainable design" will simply become "design" in planning vocabulary across the industry.

Every brief should specify the minimum environmental key performance indicators and objectives for the project. At Masdar City, we start with our best estimates based on the following minimum design requirements. We then test, evaluate, and improve for the next project.

MASDAR CITY ENVIRONMENTAL DESIGN KEY PERFORMANCE INDICATORS (KPI)

NO.	DESIGN CRITERIA	MANDATORY DESIGN REQUIREMENT	REFERENCE BASELINE / REMARKS
01	Energy Consumption	40% reduction from ASHRAE 90.1 : 2007 Compliance with Masdar Energy Design Guidance 3.0	Estidama Pearl Building Rating System Improved Energy Performance
02	Renewable Energy Provision	75% of hot water heated by solar energy	Estidama Pearl Building Rating System Renewable Energy
03	Interior Water Use	40% reduction of interior water demand	Estidama Pearl Building Rating System Water Calculator
04	Exterior Water Use - Landscaping	Average landscape irrigation demanded to be less than 2 litres/m2/day	Estidama Pearl Building Rating System Improved Construction Waste Management
05	Construction Waste Management	Not less than 70% of demolition and construction waste (by weight or volume) to be recycled or salvaged	Estidama Pearl Building Rating System Improved Operational Waste Management
06	Operation Waste Management	Not less than 60% of total operational waste (by weight or volume) to be diverted from landfills and incineration. This is reduced to 50% for Multi-Residential Buildings	Estidama Pearl Building Rating System Improved Operational Waste Management
07	Embodied Carbon in Materials	15% reduction in the overall construction for concrete structure buildings	650KgCo2e/m2
08	Sustainability Rating System	Minimum 3 Pearl under Estidama Pearl Building Rating System	Estidama Pearl Building Rating System
09	Building Performance Monitoring	Design and implement monitoring strategy for major energy & water uses at building level tenant level	Estidama Pearl Building Rating System Energy Monitoring & Reporting + Water Monitoring & Leak Detection

INTEGRATED DESIGN PROCESS

PASSIVE DESIGN

The UAE's extreme heat, which can soar up to 50 degrees Celsius in the summer, poses a major challenge for sustainable developers. To ensure optimal comfort and minimal carbon emissions from cooling, buildings must be designed to prevent heat ingress and enhance air circulation.

At Masdar City, this is achieved through passive design, which leverages the building's physical components and the natural environment to shield occupants from the elements instead of relying solely on technology.

In essence, we design buildings as if we do not have the luxury of air conditioning to cool them — much like building designers did in this region hundreds of years ago. Only after optimizing the mass and orientation of the building do we add the air-conditioning back into the design.

Examples of passive design techniques include the following:

Buildings are intentionally shaped to reduce their surface area, or the external area warmed by the sun. This reduces heat gain and helps the building stay cooler.

Buildings are oriented strategically to reduce solar gain. Placement is determined by the pathway of the sun, with windows avoid facing directly to the east or west as much as possible. When windows do face the sun, creative angling and shading are used to reduce solar gain.

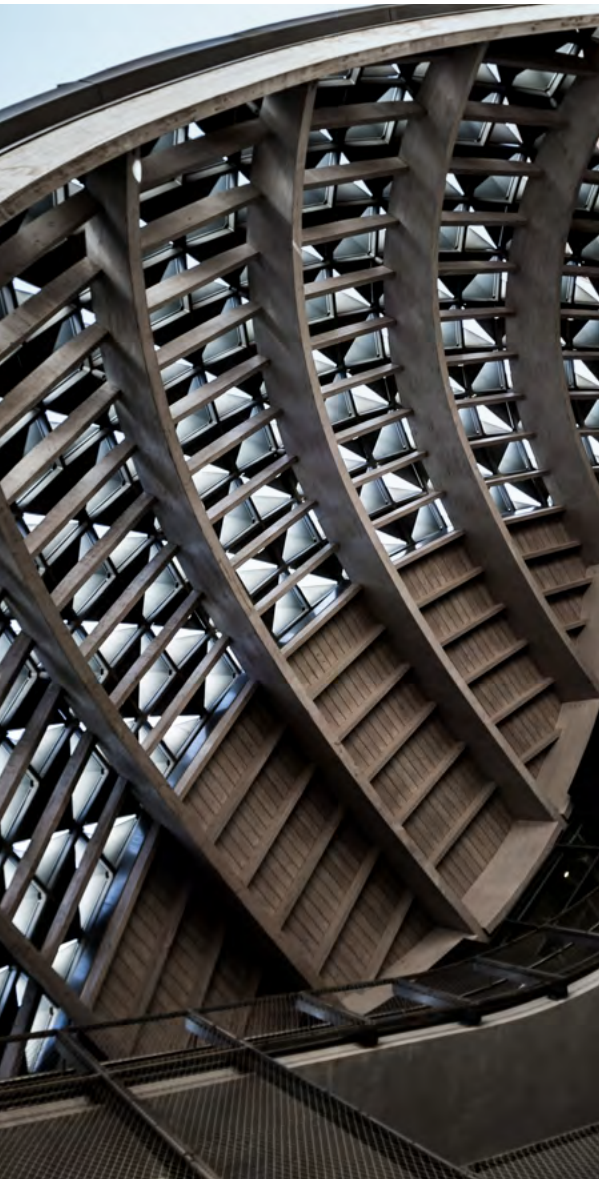
Building envelopes are airtight to ensure heat stays out while cooled air stays in. Our designers are particularly careful about the interfaces between different materials, such as where a window meets a wall.

Building envelopes are also well-insulated to minimize the transfer of heat from the outside in.

Building envelope materials have high albedo, or v, to reflect sunlight and reduce heat gain.

Colors are chosen to look clean even when they are dirty to reduce maintenance requirements, including the use of water.

By applying these principles of passive design creatively and rigorously, we have frequently achieved energy savings of 50% or more in our buildings compared to conventional designs, demonstrating our leadership and expertise in the field.



ACTIVE DESIGN

When passive design solutions have been maximized, we use active design to further reduce energy and water requirements. This includes using high-efficiency mechanical, electrical, and plumbing systems, using active shading systems, collecting condensate water from air conditioning systems, and building management systems.

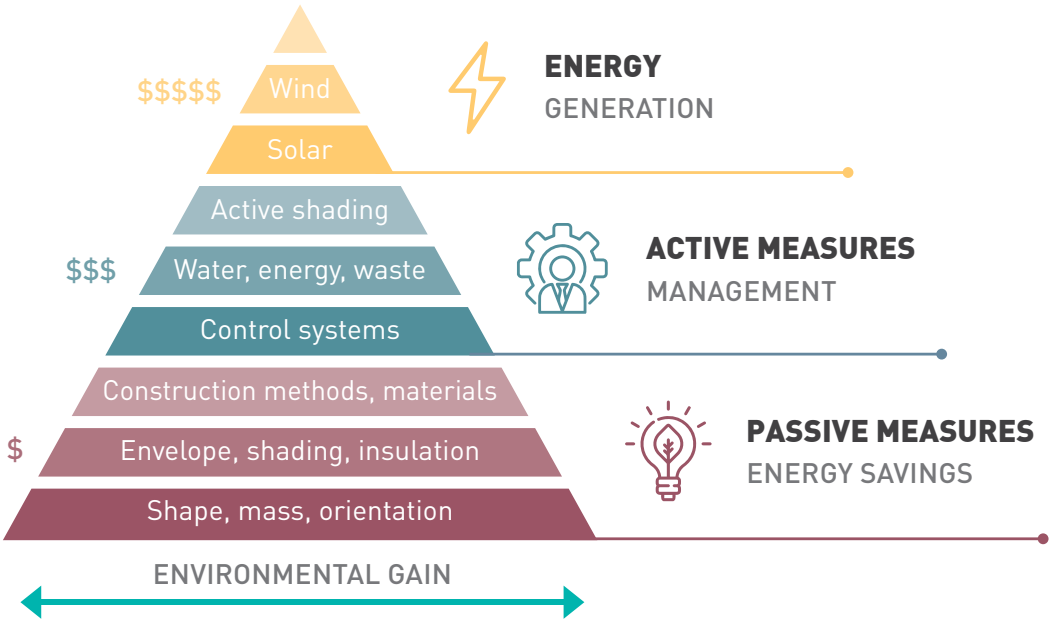
APPLIED TECHNOLOGIES

After passive and active design elements are exhausted, we then use applied renewable technologies to further reduce and offset energy requirements. Examples include wind power, geothermal energy, and, most commonly used at Masdar City, solar panels.

LOW COST, HIGH REWARD

We base our approach on passive design strategies, and enhance them with active design elements and suitable technologies. This allows our designs to achieve optimal results with minimal costs. Angling and orienting windows away from direct sun, for example, reduces the need for cooling without impacting the cost of development.

Applied technologies play an important but comparatively smaller role in sustainable design, and they come with an increased cost. The diagram below helps illustrate our approach.



CASE STUDIES

MOHAMED BIN ZAYED UNIVERSITY OF ARTIFICIAL INTELLIGENCE (MBZUAI)

From its inception, Masdar City has contributed to developing a knowledge based economy in the UAE, which meant that educational institutions were a vital component of the master plan. The Mohamed bin Zayed University of Artificial Intelligence is a graduate research university dedicated to advancing AI and has taken up several buildings in Masdar City for its campus and student residences.

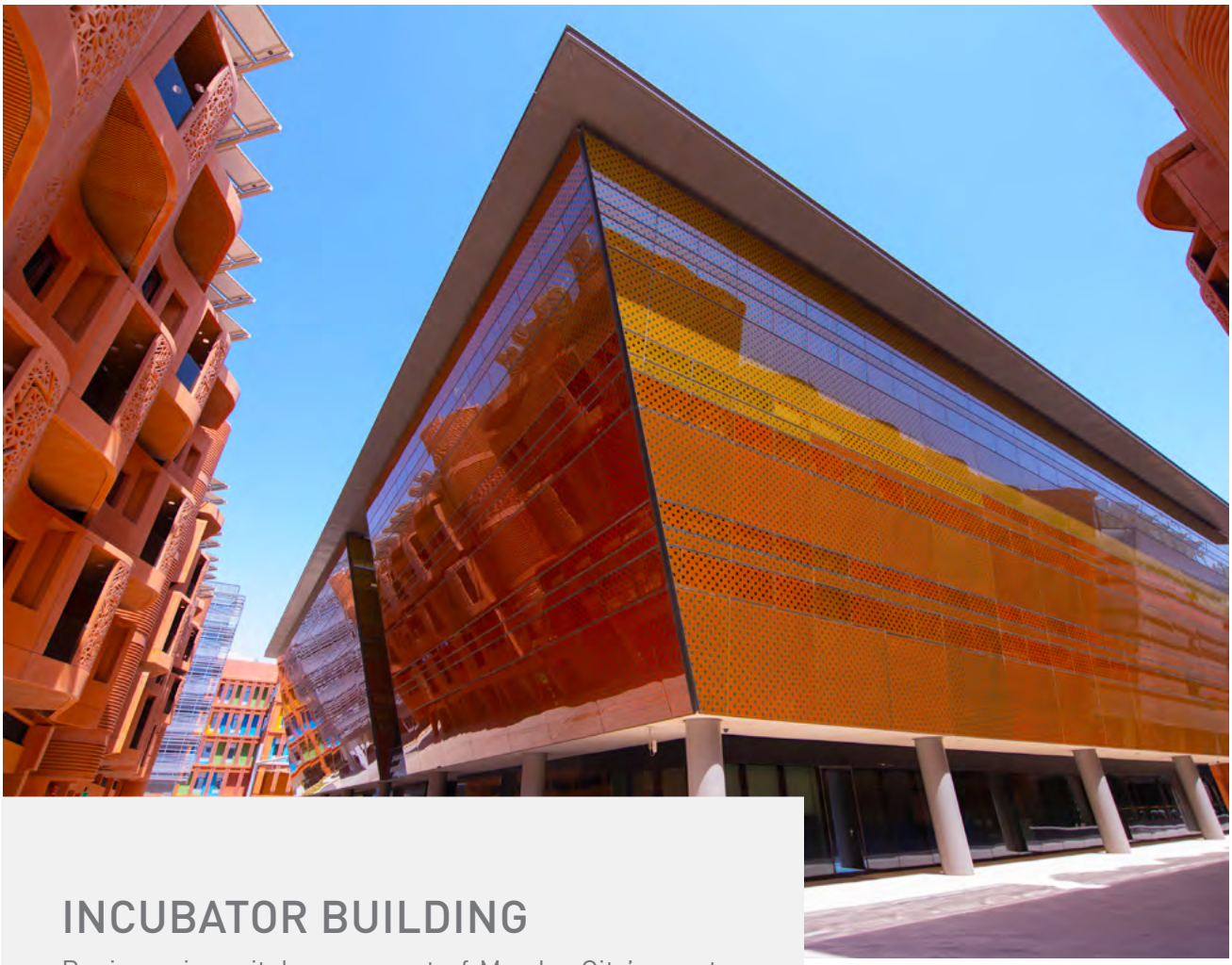
The designers made significant strides in pushing the boundaries of sustainable design and reducing carbon footprints through passive design strategies. For instance, the façades of the student accommodations and laboratory buildings optimized the number of glazed openings in combination with shading and heavy thermal insulation. These features reduced the buildings' energy demand by approximately 50 percent compared to international baselines. Additionally, one megawatt (MW) of rooftop photovoltaic (PV) solar panels was installed to further offset the energy demand.

Sustainability also influenced the color choice for the student residences. The distinctive terracotta shade, reminiscent of desert sand, is less resource-intensive to maintain than other colors. It appears relatively clean even when covered in dust, thereby reducing water usage for cleaning.

The library building, known as the Knowledge Center, serves as another exemplary case study in passive design. Similar to the student residences, it optimizes the window-to-façade ratio. Windows are strategically placed on the north and south sides to minimize direct sunlight while maximizing natural light. The south-facing wall, predominantly glass, showcases the view of one of Masdar City's parks, yet it is ingeniously designed. Angled and shaded by a wood overhang, it reduces solar gain effectively.

We often say that the sun designed the overhang: the curve follows the sun's path throughout the day, nearly touching the ground on the east and west sides. This design resembles a baseball cap bill, providing shade while allowing the glass wall to admit ample natural light without direct sunlight.

In line with the city's master plan, all university buildings sit on a podium area 7.5 meters above ground level to maximize wind flow and enhance cooling. Buildings are positioned close together to shade streets, paths, and courtyards. The streets are aligned along a northwest axis to facilitate breezes through the campus, offering additional thermal comfort and encouraging walking.



INCUBATOR BUILDING

Business is a vital component of Masdar City's master plan, driving innovation and generating the capital necessary for sustained growth. The Incubator Building, completed in 2012, serves as the headquarters of Masdar City and its Free Zone. Designed around a central courtyard to maintain cool air and encourage outdoor walking, the building exemplifies our commitment to sustainability.

The building's façade is particularly noteworthy for its role in minimizing cooling requirements. The glass sides are slanted, reducing solar gain by over a third. Inlaid porcelain circles, known as fritting, filter direct sunlight. These dots are color-coded to match sunlight levels: yellow and reflective at the top, where solar radiation is most intense, transitioning to cooler colors towards the base, enhancing comfort at street level. Horizontal bands of shading, positioned at ceiling and desk height, balance light quality and reduce heat gain.

Incorporating these innovative design features, combined with a high-performance building envelope and insights from the MBZUAI project, resulted in an approximately 45 percent reduction in energy demand.

SIEMENS BUILDING

Economic sustainability in the for of commercial viability of the Siemens building project compelled Masdar City's team to push the boundaries of passive design possibilities.

The Siemens Building is compact in form, being practically square on plan. Compact buildings can lead to less façade area which, in the case of Masdar City, reduces heat transfer from the exterior to the interior of the building. This approach to passive design also has cost benefits since less façade area requires less quantities of construction material to complete the building envelope.

Departing from the typical glass box style of corporate offices, the Siemens building features a window-to-façade ratio of about 35 percent, significantly reducing solar gain. The window design of the street facing walls comprises of horizontal strips. The adoption of simple forms and details allow a high level of airtightness to be achieved, which in turn reduces the energy loss due to leakage of conditioned air.

Furthermore, the windows are shaded to prevent direct sunlight from heating the building's interior. The external shading elements comprised of lightweight aluminum shading panels characterized by distinctive "fins" of varying forms. These fins are shaped to balance blocking excess sunlight with maximizing views and daylight. Additionally, nine atriums allow natural daylight to permeate the interior office spaces.

At the time of construction, PV panels were too costly to power the building. However, several solar thermal panels were installed on the roof to heat water, reducing the building's annual energy requirements by an additional two percent.

Overall, the Siemens building was designed and equipped to use 46 percent less energy than international baselines.

IRENA

The development of the new headquarters for the International Renewable Energy Agency (IRENA) employed a strategic approach. IRENA and Masdar City collaborated on a meticulous brief to ensure that every square meter of space served a purpose, eliminating wasted space and reducing the need for cooling.

With a fixed construction budget, the design and construction teams were committed to pushing the boundaries of what was achievable within financial constraints.

The result was a landmark achievement: Abu Dhabi's first 4-Pearl rating within the Estidama Pearl Building Rating System, surpassing the Siemens building by one pearl.

This project also underscored the social dimension of sustainability through an unexpected insight.

The IRENA Building features three cores surrounding a triangular atrium. Originally, the design included an open-air, shaded courtyard. However, concerns about the courtyard's usability during the summer months led to a pivotal decision. A truly sustainable space must meet the needs of its occupants, irrespective of carbon emissions.

Thus, the courtyard was enclosed and transformed into an air-conditioned atrium, creating a social hub usable year-round. This decision prompted questions about the energy required to cool the atrium, but the challenge spurred innovative solutions.

In the UAE, summer temperature differences between the exterior and interior of buildings can exceed 20 degrees Celsius, leading to significant heat transmission. High-performance thermal insulation is essential to mitigate this effect.

Enclosing the courtyard redefined the building's thermal dynamics. The previous external walls became internal walls, shifting the primary heat defense to the atrium roof. This change reduced the external building envelope's surface area, offsetting the energy required to cool the atrium.

Moreover, the installation of PV panels on the roof achieved an additional energy reduction of about 8 percent. Combined with passive design strategies, this led to an overall energy demand reduction of over 40 percent compared to international baselines.

THE ECO-RESIDENCES

Masdar City seized the opportunity to test the boundaries once again with the Etihad Eco Residences project, delivering a bespoke series of buildings providing 500 residential units for Etihad Airways. These units aimed to minimize travel for flight crew to and from the airport while optimizing energy and water use.

The project achieved a 43 percent overall energy reduction, thanks to passive design features such as highly insulated walls, optimized window openings, airtight building envelopes, efficient distribution of building services, and solar water heaters. Originally targeting a LEED Gold certification, the building exceeded expectations by earning a LEED Platinum rating.

NZ1

By 2020, Masdar City was home to numerous green buildings including 21 buildings that have achieved LEED Platinum certification. However, we remained focused on the future and Masdar City's original objective: achieving net-zero emissions. We recognized the potential to push further, having already accomplished net-zero energy in a villa prototype in 2017, known as the Eco-Villa. The next challenge was to develop a net-zero energy commercial building. Furthermore, to be a catalyst of change in the real estate industry, we needed to create a replicable "green-print". With this in mind, we decided to take a straightforward, efficient and humble approach to the design.

Drawing on over a decade of sustainable development expertise, we integrated lessons learned—such as advanced air-tight building envelopes, high-performance insulation, optimized window-to-façade ratios, and strategic solar shading and orientation. Our approach resulted in an impressive 53 percent reduction in energy demand compared to standard benchmarks, marking it as Masdar City's most energy-efficient building to date.

The declining cost of PV solar panels made it financially viable to cover the building's roof and parking structures with PV panels, generating sufficient energy to meet the building's annual consumption, thereby achieving net-zero energy.

Construction of NZ1 was completed in October 2023, in time for COP28, marking a significant milestone as the UAE's first net-zero energy-designed commercial building. It is on track to achieve LEED Platinum, LEED Zero, and Estidama 4-Pearl certifications, reaffirming its position as a beacon of sustainable architecture and setting a new standard for future developments. The success of NZ1 has already sparked interest from other tenants, eager to replicate its groundbreaking environmental achievements.

THE FUTURE: MASDAR CITY SQUARE

Masdar City Square, currently under construction and planned for completion in 2025, stands as one of our most ambitious projects to date. Comprising seven commercial buildings, this development integrates our extensive experience in sustainable design to achieve net-zero energy on a larger scale. Each building is on track to attain LEED Platinum and Estidama 4-Pearl ratings.

The focal point of Masdar City Square will be the iconic 12,000-square meter headquarters building, which is on track to achieve the Zero Energy certification from the International Living Future Institute.

Passive design strategies have already reduced the building's operational energy needs by a projected 43 percent compared to baseline standards. To meet the remaining energy demands, PV solar panels are strategically integrated into the design. Rather than traditional rooftop placement, these panels will adorn the building in a canopy formation, optimizing their angle and placement to generate 104 percent of the building's annual energy requirements. Surplus electricity will be channeled back into the local grid.

Beyond environmental sustainability, Masdar City Square emphasizes the social dimension of urban development. Placing a strong emphasis on walkability and community engagement, the design fosters gathering spaces that enhance the overall experience of the development. In addition to standard green certifications, Masdar City Square aspires to achieve WELL Gold certification from the International Well Being Institute, underscoring its commitment to promoting the health and well-being of its occupants.

THE FUTURE: THE LINK

The Link, currently under construction and scheduled for completion in 2025, represents another bold venture for Masdar City. Similar to Masdar City Square, each building within The Link is poised to achieve LEED Platinum, Estidama 4-Pearl, and WELL Gold certifications.

Unlike Masdar City Square, however, The Link is a comprehensive mixed-use development. It integrates residential and commercial buildings, event and retail spaces, and recreational areas such as playgrounds, all designed to foster a cohesive, walkable community.

Central to The Link's innovation is CO-LAB, a pioneering concept unprecedented in this region. Anticipating future trends in work dynamics and aligned with Masdar City's entrepreneurial focus, CO-LAB integrates shared living and working spaces within a net-zero energy framework.

Through meticulous passive and active design approaches, the CO-LAB building is projected to achieve a remarkable 51 percent reduction in energy consumption compared to international standards. PV solar panels strategically placed on the roof and adjacent parking structures will generate 114 percent of the building's annual energy requirements, achieving net-zero energy status. Excess electricity will contribute to the local grid, further enhancing sustainability efforts similar to Masdar City Square.

THE FUTURE: NET-ZERO ENERGY MOSQUE

One of our recent groundbreaking projects is the development of a net-zero energy mosque, initiated in 2024. This endeavor not only emphasizes social, economic, and environmental sustainability but also explores cultural sustainability.

The mosque's employs a concrete primary structure which supports walls built from rammed earth, a traditional building method found in Middle Eastern architecture. Beyond its cost-effectiveness, rammed earth provides excellent insulation and fosters a strong sense of local identity and community.

A series of tiered windows on the roof will illuminate the interior with natural light patterns, creating a serene atmosphere and facilitating natural ventilation that minimizes reliance on air conditioning, particularly beneficial during the winter months. Outdoor colonnades will offer shaded pathways, enhancing the transition from outdoor spaces to the inner sanctum of the mosque.

Designed to accommodate 1,300 worshippers, the mosque will generate at least 100 percent of its annual energy needs through on-site PV panels. The building's overall energy demand is projected to be reduced by 35 percent compared to international standards. Water conservation measures include low-flow fixtures, drought-resistant landscaping, and recycled water for irrigation, is projected to achieve a 55 percent reduction in water usage.

In addition to targeting a Zero-Energy certification from the International Living Future Institute, the mosque aims for LEED Platinum, Estidama 4-Pearl, and WELL Gold ratings, reflecting its comprehensive approach to sustainability across multiple dimensions.

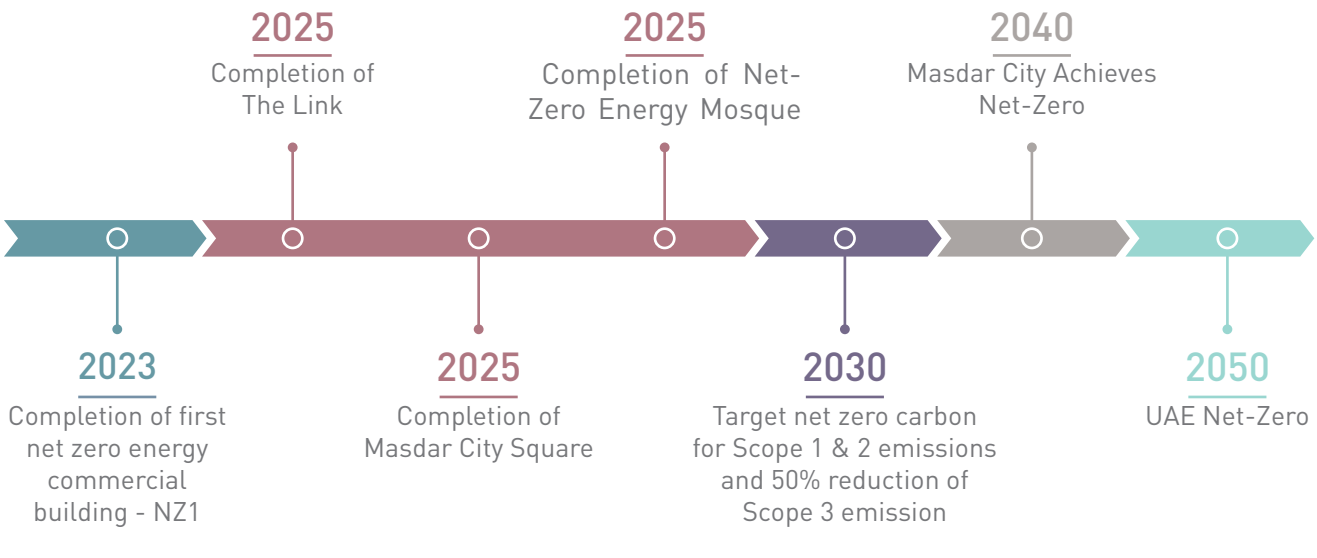
MASDAR CITY'S ROADMAP TO NET-ZERO

Masdar City Square and The Link each feature only one net-zero energy building. The reason for only one in each development involves multiple factors, with space being a significant limitation. Currently, even our most energy-efficient buildings require a substantial number of PV solar panels to achieve net-zero energy. In dense urban areas, it remains challenging to install enough panels across entire developments.

However, the keyword here is "yet". Masdar City has consistently demonstrated that continuous innovation and pushing boundaries yield significant advancements. A decade ago, achieving 40 percent energy and water savings was considered our best outcome. Today, net-zero energy stands as the standard for new buildings. Our next milestone is entire net-zero energy developments.

By 2030, our goal is to achieve net-zero for direct carbon emissions and those associated with the energy we procure (Scope 1 and 2 emissions), alongside a 50 percent reduction in carbon emissions from our supply chain (Scope 3 emissions).

By 2040, through deep engagement with our supply chain partners, ongoing advancements in energy efficiency, robust carbon offsetting initiatives, and increased investment in rooftop solar power, we aim to achieve overall net-zero. From 2040 onwards, we will continue to adapt and innovate to further support the UAE 2050 Net-Zero target.



NET-ZERO CARBON VS. NET-ZERO ENERGY

Before digging deeper into this roadmap to net-zero, we need to understand the significant difference between net-zero and net-zero energy. Net-zero energy addresses carbon emissions related to energy use. As outlined above, energy-related carbon emissions account for only a portion of a building or city's total carbon emissions. To achieve net-zero energy city-wide, we need to find ever-more innovative and creative ways to reduce energy demand even further and generate clean, renewable energy for our remaining requirements.

The meaning of net-zero is slightly different from net-zero energy. In practice, it refers to net-zero carbon. Achieving net-zero carbon, even just in the built environment, is a far greater task than achieving net-zero energy. It means finding a way to reduce and offset all of a building's carbon emissions, including those related to construction and demolition. Sometimes called embodied carbon emissions, **this category of carbon represents the vast majority** of a building's total carbon emissions.

A MULTI-FACETED APPROACH

The following sections detail our comprehensive strategy towards achieving net-zero by 2040. While tailored to our specific geographic and economic context, we are confident that our approach is adaptable, offering valuable insights for cities worldwide embarking on their own sustainability journeys.

STEP 1: ASSEMBLE THE RIGHT TEAM

Assigning multiple disciplines and a client representative to a team marks just the beginning of effective collaboration. Each discipline must possess a fundamental understanding of the others to collaborate successfully. Leadership within the team is crucial, guiding members to integrate diverse perspectives and ideas. Often, optimal solutions arise not from any single discipline but from the synergy between them, as diverse experts creatively collaborate to tackle challenges.

CASE STUDY: FINDING SOLUTIONS ACROSS DISCIPLINES

During the design phase of a development in Masdar City, an issue arose regarding excessively high ceiling voids. Initially, it was observed that the ceiling void near the mechanical plant rooms needed to accommodate numerous air ducts. However, upon closer inspection of the building's layout, it was discovered that the ceiling void at the opposite end of the building, far from the mechanical plant room, contained very few air ducts. This inefficiency prompted a reevaluation aimed at optimizing space usage and reducing cooling demands.

In an experimental approach, the team decided to switch roles between the architect and the mechanical engineer. This change empowered the mechanical engineer to plan the building from their technical perspective, and conversely for the architect. Within a week, a new plan emerged: the mechanical rooms were strategically integrated into the building's design, relocating them from peripheral "leftover" spaces to a central position. This adjustment significantly shortened the air duct routes, enhancing efficiency. Consequently, the ceiling voids were reduced by nearly half a meter per floor, leading to a total building height reduction of over two meters. This not only saved costs but also lowered operational and embodied carbon emissions by minimizing the façade area.

STEP 2:
ADOPT A HOLISTIC PHILOSOPHY OF SUSTAINABILITY

At Masdar City, we start with a fundamental commitment to holistic sustainability. Unlike many architectural approaches that begin with a sustainable design and adjust for budget constraints, our process prioritizes environmental, economic, and social sustainability from the outset. Each of these pillars is integral; compromising one jeopardizes the overall sustainability of the project. A building may be environmentally friendly, but if it fails to meet user needs or is economically unsustainable, its sustainability is compromised.

Our objective is not merely to achieve accolades like LEED Platinum or net-zero energy in the initial attempt. Instead, we aim to maximize sustainability within existing parameters. Through continuous innovation, boundary-pushing, and strategic investments in advanced technologies, we steadily advance towards our sustainability goals.

STEP 3:
FOCUS ON PASSIVE DESIGN

While Masdar City has tailored its approach to effectively manage extreme heat, passive design principles that harmonize with local environments can prove equally effective worldwide, regardless of climate. While advanced technologies play a role in optimizing energy and water usage, our most efficient buildings start with straightforward design choices and strategic supply chain decisions.

For instance, optimizing the ratio of windows to facade area, employing airtight building envelopes, and integrating high-performance insulation are effective strategies that provide insulation benefits against both heat and cold. While high-performance materials may initially incur higher costs, these investments are offset by savings in other areas. Standardizing window sizes and material cuts reduces costs and minimizes waste. Utilizing locally sourced materials not only cuts expenses but also reduces carbon emissions associated with transportation.

In the UAE, this approach includes utilizing local and recycled materials like aluminum and concrete, as well as incorporating natural materials such as rammed earth. Adapting this strategy for North America might involve leveraging abundant local resources such as timber, which can be sustainably harvested and renewed.

STEP 4: MINIMIZE ENERGY USE

At Masdar City, we emphasize that the most sustainable energy is the energy we conserve. By minimizing our energy demands, we accelerate the journey towards net-zero. Simply put, reducing our reliance on clean and renewable energy from the grid shortens the path to eliminating fossil fuels from our energy mix.

Achieving minimal energy consumption starts with a thorough audit of our primary energy uses. At Masdar City, electricity accounts for the largest portion of our daily energy consumption, powering lighting, appliances, electronics, and essential cooling systems—critical in our hot UAE climate.

Our approach centers on optimizing building design to reduce energy demand, integrating passive design principles alongside active strategies such as efficient mechanical systems and effective shading solutions. Additionally, we implement operational optimizations to further curb energy use. For instance, our lighting systems are not only responsive but also monitored by facilities teams to adjust light and cooling based on occupancy and time of day.

Maintenance practices also play a pivotal role in energy efficiency across our buildings and public spaces. Similar to maintaining cars for optimal fuel efficiency, regular upkeep ensures our infrastructure performs efficiently. This includes repairing window seals, optimizing irrigation systems, and cleaning solar panels to maximize their effectiveness.

STEP 5: USE RENEWABLE ENERGY AND MINIMIZE DEPENDENCE ON FOSSIL FUELS

The UAE is a significant producer of solar power and home to the world's largest single-site solar plant. With an average of 360 sunny days annually, it's clear why solar PV panels are both highly efficient and cost-effective for generating renewable energy in this region.

Similarly, regions with different climatic conditions can leverage local natural resources to achieve sustainable energy solutions. In Canada, for example, which boasts the most lakes globally, hydroelectricity constitutes 61 percent of the energy mix. Meanwhile, in the wind-rich United Kingdom, wind power leads as a primary renewable energy source.

The key lies in designing infrastructure that harmonizes with its environment rather than opposing it—a principle adhered to long before the era of electric heating and cooling. This approach remains effective and essential today.

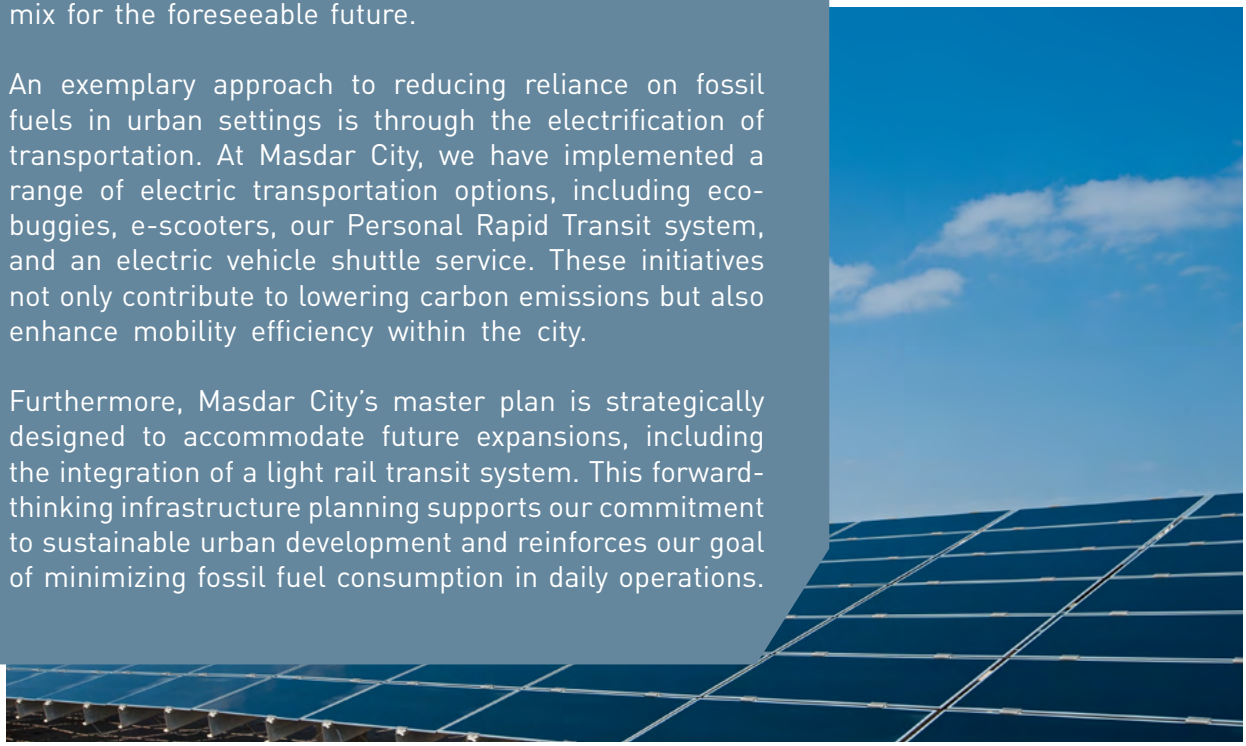
In densely populated urban areas, maximizing renewable energy adoption requires creativity and innovation. For instance, in Masdar City and other parts of the UAE, integrating PV panels over parking areas serves a dual purpose: providing shade for vehicles while generating clean, renewable energy.

STEP 6: LOOK FOR OTHER OPPORTUNITIES TO MINIMIZE FOSSIL FUELS

As we move towards achieving net-zero emissions by 2050, it is crucial to accelerate the transition away from fossil fuels wherever feasible and as swiftly as possible, while acknowledging their continued role in the global energy mix for the foreseeable future.

An exemplary approach to reducing reliance on fossil fuels in urban settings is through the electrification of transportation. At Masdar City, we have implemented a range of electric transportation options, including eco-buggies, e-scooters, our Personal Rapid Transit system, and an electric vehicle shuttle service. These initiatives not only contribute to lowering carbon emissions but also enhance mobility efficiency within the city.

Furthermore, Masdar City's master plan is strategically designed to accommodate future expansions, including the integration of a light rail transit system. This forward-thinking infrastructure planning supports our commitment to sustainable urban development and reinforces our goal of minimizing fossil fuel consumption in daily operations.



STEP 7: MINIMIZE WATER USE

Achieving net-zero also necessitates minimizing water usage, particularly crucial in regions like the UAE, where potable water is scarce and desalination of seawater and groundwater is both challenging and costly.

Masdar City has implemented several measures to reduce water consumption by approximately 40 percent compared to recognized benchmarks such as LEED and Estidama. We employ low-flow water fixtures and high-efficiency appliances in kitchens and bathrooms to minimize water usage and reduce waste. Additionally, we collect condensate water from air conditioning systems and recycle greywater for irrigating green spaces in our public areas. The selection of drought-resistant vegetation further mitigates water demand in outdoor environments.

STEP 8: MANAGE WASTE

Waste management plays a critical role in achieving sustainability and progressing towards net-zero goals. From an operational standpoint, diverting construction waste from landfills is paramount. We meticulously plan and design using standard sizes and cuts to minimize unnecessary waste during construction. Additionally, we prioritize materials that are recyclable and implement an on-site recycling facility to divert a substantial portion of our waste.

In our day-to-day corporate operations, optimization is achieved through careful planning, education, and collaboration. We adhere to the principles of reduce, reuse, and recycle, employing waste sorting systems within our offices to separate plastic, paper, food, and general waste effectively. To minimize single-use plastic, we utilize washable dishes and cutlery for kitchen use at Masdar City's headquarters, and serve beverages in porcelain or glass cups. Water is provided in reusable glass bottles, and we actively discourage unnecessary printing, encouraging electronic workflows whenever possible.

These measures collectively contribute to reducing our carbon footprint. While each initiative may yield a modest impact individually, we firmly believe in the cumulative effect of scaling these efforts, driving significant positive change towards sustainability.

STEP 9:
MEASURE CARBON FOOTPRINT

Measuring the carbon footprint is a crucial step on the journey to achieving net-zero. It involves setting a baseline, assessing the key sources and drivers of carbon emissions, and creating a systematic plan to address them.

Carbon footprint measurement is a complex process. To measure and plan effectively, cities need to establish boundaries regarding what can be measured, what can be changed, and what cannot be changed.

The following is a **summary of Masdar City's energy, water, and waste reductions in 2022,** as well as our production of renewable energy:

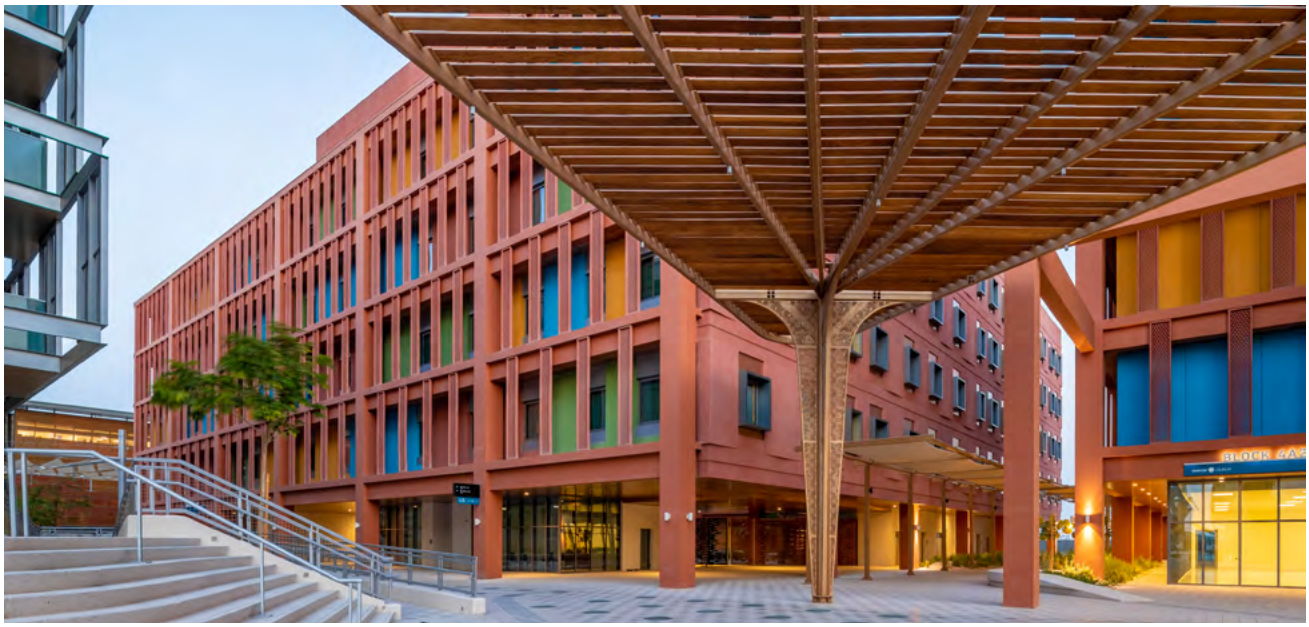
By using passive and active design strategies, we were able to reduce demand for energy within our buildings by 38.4 percent compared to international baselines, or about 21 million kilowatt hours, which is roughly equivalent to taking 1,600 cars of the road.

We were able to reduce water use by 28.7 percent, or about 67 million litres, which is roughly equivalent to filling 27 Olympic-sized swimming pools.

We reduced operational waste by 66 percent through effective waste management and diversion.

On-site PV solar panels, including those located on buildings, parking structures, and within our 10 MW solar farm, produced about 13 million kilowatt hours of energy to return to the grid, or the equivalent of about 37 percent of Masdar City's total energy requirements.

All the above figures translate into carbon emissions reduction, offset, or avoidance.



Carbon reduction and avoidance involve the direct efforts to emit less carbon into the atmosphere. When we talk about carbon offset, it's akin to a credit system. By generating renewable clean energy and integrating it into the grid, we offset the emissions that would otherwise result from producing an equivalent amount of energy using fossil fuels.

The following is a summary of our carbon reduction, avoidance, and offset achievements for 2022:

We reduced our direct carbon emissions by 257 tCO2e (metric tonnes of carbon dioxide equivalent) compared to 2019. (Note: We compare to 2019 rather than 2020 or 2021 due to COVID-19. Remote work impacted building operations and energy and water use, making 2019 a more accurate year for measuring "standard" operations.)

In 2022, we offset a total of 4,810 tCO2e of energy-related carbon emissions through the production of renewable energy.

Through our efforts to reduce and optimize energy and water use, we avoided a total of 7,416 tCO2e of energy-related carbon emissions and 775 tCO2e of water-related carbon emissions.

Recycling initiatives allowed us to avoid 417 tCO2e of waste-related carbon emissions.

SCOPING CARBON EMISSIONS

Standard practice is to look at carbon emissions within three different scopes. This approach and terminology come from Greenhouse Gas Protocol, the industry standard for greenhouse gas accounting.

Categorizing emissions in this way helps us analyze carbon emissions by source, which impacts our reduction strategies.

Scope 1 emissions are direct emissions that are owned or controlled by the company, or emissions for which we have direct responsibility. For example, at Masdar City, Scope 1 emissions include emissions from fire suppression systems and standby diesel generators for emergency power. It also includes emissions related to Masdar City-owned vehicles used to visit construction sites. Scope 1 emissions represent the smallest proportion of Masdar City's total carbon emissions.

Scope 2 emissions are indirect emissions related to purchased energy. At Masdar City, Scope 2 emissions include emissions related to the energy we use on a day-to-day basis, including electricity and district cooling. Scope 2 emissions represent our second biggest carbon footprint.

Scope 3 includes any indirect emissions that occur in our value chain. At Masdar City, this includes carbon emitted from the construction of new buildings, which is often called "embodied carbon." Scope 3 emissions also include energy used by our tenants, other purchased goods and services, such as food, paper, and electronics. At Masdar City, our Scope 3 emissions account for our largest carbon footprint.

This level of scoping and analysis yields important insights about challenges and priorities. Thanks to ongoing measurement of greenhouse gas inventory, we know that employee transportation to and from work accounts for only a small portion of our total Scope 3 carbon emissions, while embodied carbon accounts for the largest portion of our Scope 3 emissions. Therefore, we have dedicated most of our planning and resources to reducing embodied carbon.

For reference, industry-wide, embodied carbon accounts for approximately 58 percent of all building emissions, with operational use accounting for about 42 percent. At Masdar City, these percentages vary given the progress we have made in increasing energy efficiency. Instead of percentages, we measure embodied carbon emissions in kilograms of carbon dioxide equivalent per square meter, represented as kgCO2e/m2.

Currently, the building industry still lacks a comprehensive database of embodied carbon. This only emphasizes the need for more industry participants to start measuring embodied carbon. Across Masdar City's portfolio at the end of 2022, the average embodied carbon is about 642 kgCO2e/m2. Embodied carbon for NZ1, our first net-zero energy commercial building, was calculated to be 511 kgCO2e/m2. The embodied carbon for Masdar City Square, a considerably larger and more complex development, is on track to be approximately 568 kgCO2e/m2.

We will continue to look for ways to reduce the embodied carbon of our buildings. Bu 2030, we are targeting 400 kgCO2e/m2.

ADOPTING A LIFECYCLE ANALYSIS APPROACH

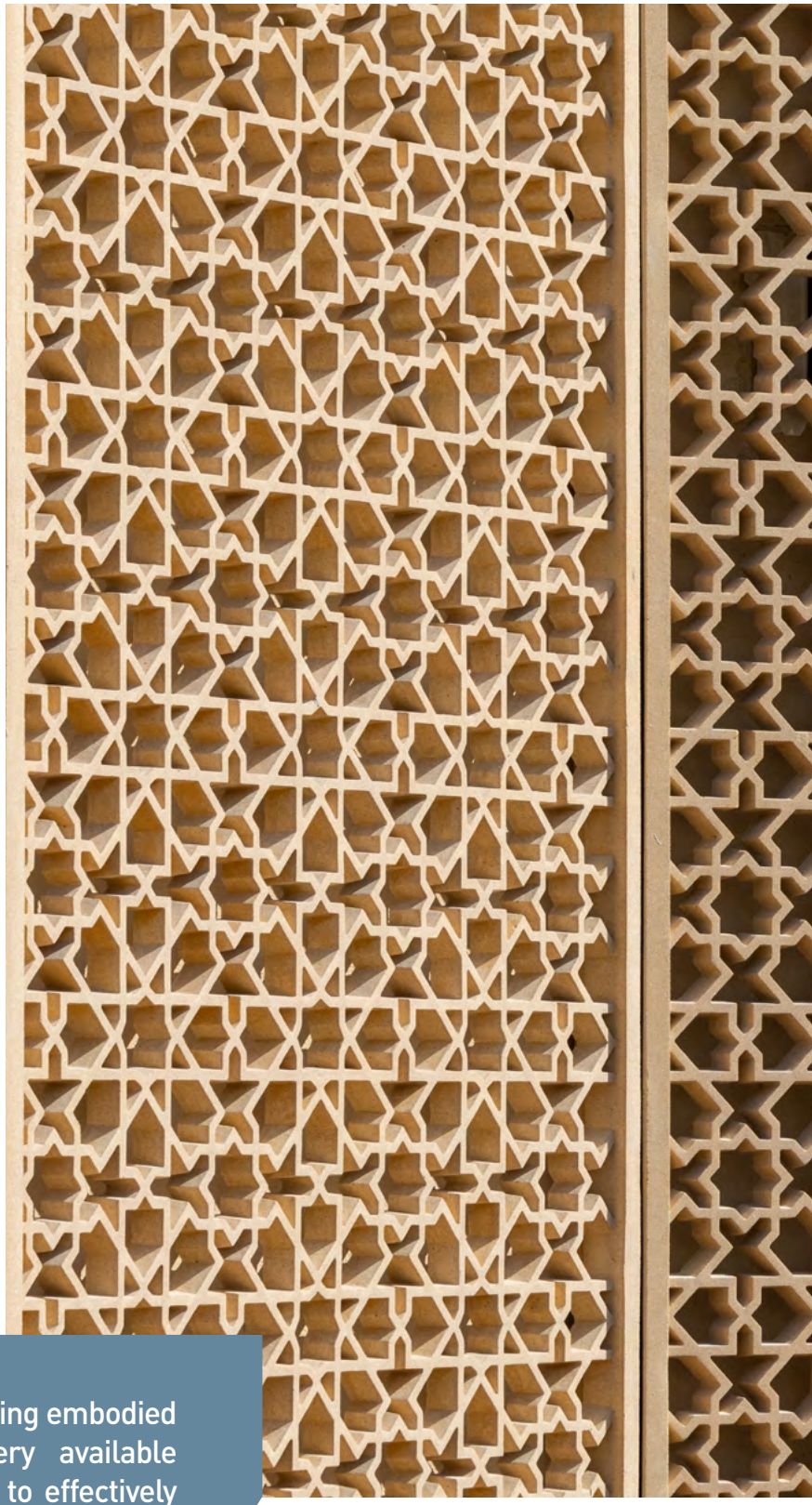
When measuring and analyzing carbon emissions, it becomes clear that emissions occur at all stages of a building's lifecycle. For instance, in Masdar City, a building's lifecycle stages include construction, operations and maintenance, refurbishment and/or re-fitting, and finally, demolition.

Each stage introduces different types and levels of carbon emissions, each presenting unique challenges. Building energy-efficient structures addresses Scope 2 emissions, while using locally sourced materials during construction helps reduce Scope 3 emissions. Achieving overall emissions reduction across the lifecycle demands meticulous planning, forecasting, and collaborative efforts.

STEP 10: ADDRESS EMBODIED CARBON

Embodied carbon, which refers to emissions related to construction, falls within Scope 3 carbon emissions. It is the **largest source of carbon emissions in the built environment** and poses a significant challenge in achieving net-zero, as it is beyond our direct operational control. This includes emissions from building construction, transportation of materials and workers, heavy machinery operation, material development like aluminum and concrete, and management of construction waste.

While PV panels and energy-efficient buildings contribute to emissions reduction, they alone cannot sufficiently offset embodied carbon. Addressing embodied carbon requires extensive collaboration with our supply chain to adopt more sustainable practices and materials. It also necessitates leveraging emerging technologies, committing to a circular economy, and investing in nature-based solutions such as mangrove planting.



There is no singular solution to tackling embodied carbon. It demands utilizing every available tool and innovation at our disposal to effectively mitigate its impact on our journey toward net-zero.

STEP 11:
INVEST IN INNOVATION

Even with mastery of previous steps, achieving net-zero requires challenging the status quo and establishing standards that are currently nonexistent. Creative solutions are needed to minimize emissions from waste, water, electricity, and embodied carbon. These solutions hinge on innovation and technology, areas in which Masdar City has been investing since its inception.

The Masdar City Free Zone hosts over 1,100 companies, including prominent international entities like Masdar (Abu Dhabi Future Energy Company), Siemens Energy, IRENA, and Honeywell. Additionally, we foster sustainability through The Catalyst, an investor in clean-tech start-ups focused on developing innovative solutions to combat climate change.

The above case study underscores the criticality of selecting proficient team members during the formulation of a design brief.

The essential attributes of exceptional team members remain fundamental: robust educational background, diverse expertise across multiple domains, and a proven dedication to their craft.

However, our experience has highlighted several additional qualities that are equally vital yet more challenging to discern during the interview phase: trust, empathy, and humility.

TRUST

Trust serves as the bedrock for collaboration and teamwork. It is essential for team members to have faith in each other's abilities and reliability to achieve effective cooperation. Moreover, trust enables teams to explore new frontiers. When team members trust one another, they are more inclined to take calculated risks and freely share their ideas without apprehension of criticism. This fosters a culture conducive to creativity and innovation, where diverse perspectives can flourish and novel solutions can be discovered.

EMPATHY

Empathy, the capacity to comprehend and resonate with others' emotions, is pivotal for grasping the perspectives, needs, and challenges of fellow team members. A team that cultivates a culture of mutual assistance and support tends to outperform those characterized by competition or siloed operations. In addition, empathy is instrumental in conflict resolution. By empathizing with different viewpoints and seeking common ground, teams can nurture harmonious and productive relationships, thereby enhancing overall effectiveness and collaboration.

HUMILITY

Humility entails a readiness to learn from others and acknowledge when one lacks complete knowledge or solutions. A team that lacks openness to learning inevitably hampers innovation, as creativity thrives on embracing novelty and the unfamiliar.

Humble team members prioritize collective success over personal recognition. This fosters a positive team environment where each individual feels valued and is motivated to contribute their best efforts.

CONCLUSION

This roadmap is not a mere collection of isolated actions, but a bold and coherent vision. Each action is vital, but on its own we recognize it is not enough, to achieve net-zero in the built environment. Instead, each action reinforces the others, demanding a high level of coordination and cooperation.

This vision is what has inspired Masdar City since its inception. Our success is based on our holistic approach that considers every dimension of sustainability. We have learned by doing, by experimenting, by innovating, and by adapting.

The challenge of climate change is not only a scientific or technical one, but also a creative and collaborative one. It requires us to reimagine how we design, build, and operate our cities, and how we engage with our stakeholders and communities. It requires us to embrace diversity, flexibility, and resilience.

Our hope is that this roadmap will empower you and your organization to embark on your own journey to net-zero, by providing you with the knowledge, the inspiration, and the direction to achieve a more sustainable future. We know that net-zero in cities is possible, and we urge you to join us in making it a reality.

SOURCES

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08	Standards & Guidance | GHG Protocol
09	Wind energy industry in the UK - statistics & facts | Statista

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