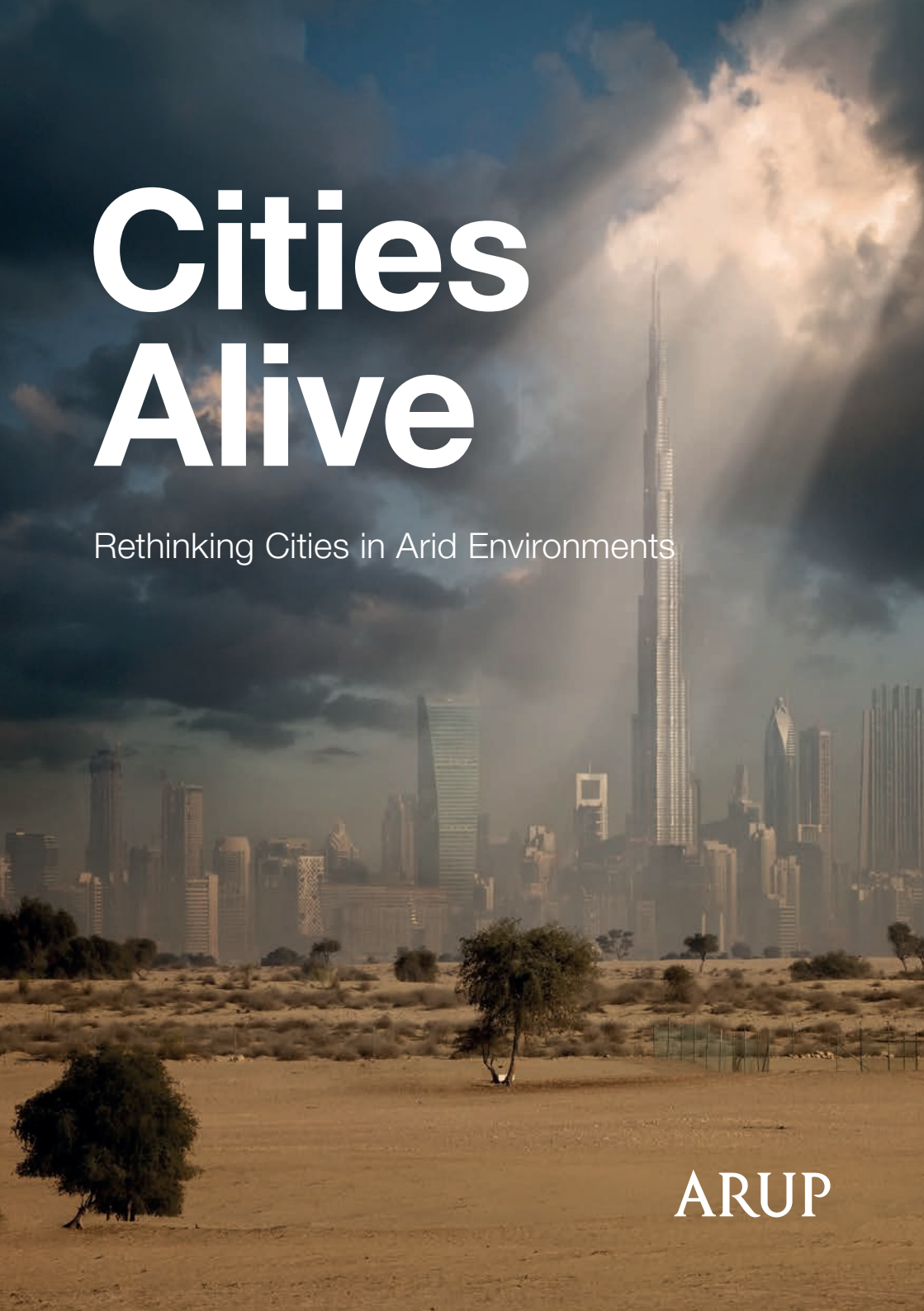
Cities
Alive
Rethinking Cities in Arid Environments
ARUP

“The chief function of the city is to convert power into form, energy into culture, dead matter into the living symbols of art, biological reproduction into social creativity.”

Lewis Mumford

◀ Jemaa El Fna, Marrakesh, Morocco

This report is the product of collaboration between Arup's Middle East Planning Team, and specialist planners, designers and engineers from across our global offices. The report has been guided by Arup's Foresight + Research + Innovation team and their extensive experience. We are also grateful for the expert contributions from a range of external commentators.

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Contents

"In arid environments cities face two main challenges, increasing temperatures and water scarcity. Through its climate adaptation plan, Dubai will build on various innovative techniques as well as the latest technologies to continue to thrive as a livable city with a healthy and sustainable environment."

Abdulla Al Basti, Secretary General
of The Executive Council of Dubai

"As a rapid-growth City in an arid environment, Austin is using the latest research and modeling on climate change to inform our 100 year water utility plan. We are also future-proofing public buildings, by using collected rainwater and recycled water for flushing and irrigation."

Steve Adler, Mayor of Austin, Texas

Foreword

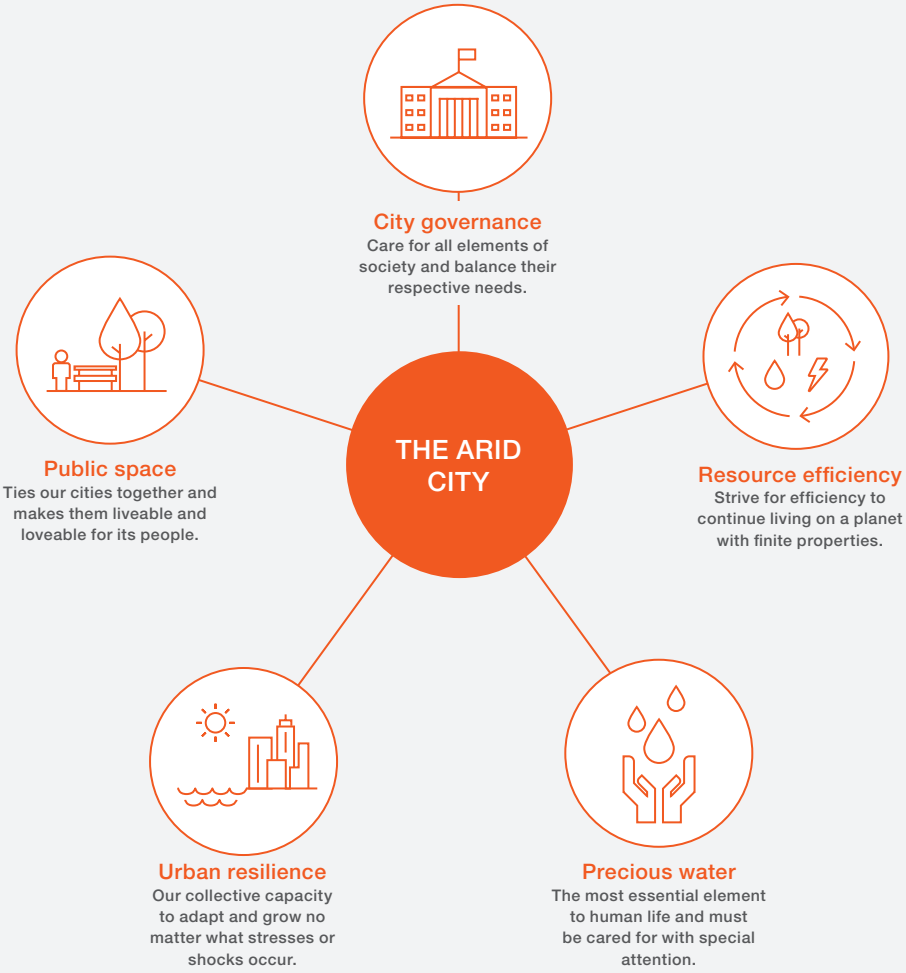
Mark Watts, Executive Director,
C40 Cities Climate Leadership Group

Climate change and its effect on global water cycles will be a defining marker of the 21st Century and will significantly impact not only the natural environment but human civilization as we know it. Tackling climate change is the biggest challenge the human race has ever faced, because it requires a fundamental shift away from the economic model that has created huge material advances over the last two hundred years. But it is also an opportunity to create a different model of living that is both more sustainable and enables every global citizen to enjoy a quality of life that is today the preserve of only a minority.

Cities are integral to tackling the global challenges of climate change and water shortage for three primary reasons. First, cities are the major theatres of climate impacts such as drought and flooding. Second, because mayors more than any other group of political leaders have demonstrated a capacity to collaborate against climate change. Third, because cities are where the future happens first and so are the birthplace of the new, clean, climate-safe and equitable world.

Arup's Cities Alive series provides an overview of future trends that cities face and how we can best understand these trends in shaping more sustainable cities. Cities Alive: Rethinking Cities in Arid Environments marks an important step towards understanding the resilience of cities facing water scarcity. It underlines the importance of considering the unique social, economic, environmental and political characteristics of each city to identify tailored solutions for cities in an arid environment.

C40 Climate Leadership Group brings together the megacities of the world to turn the Paris Agreement into action. Created and led by cities, C40 is focused on reducing global greenhouse gas emissions and climate risks.


City governance
Care for all elements of society and balance their respective needs.
Public space
Ties our cities together and makes them liveable and loveable for its people.
THE ARID CITY
Resource efficiency
Strive for efficiency to continue living on a planet with finite properties.
Urban resilience
Our collective capacity to adapt and grow no matter what stresses or shocks occur.
Precious water
The most essential element to human life and must be cared for with special attention.

Executive Summary

Hrvoje Cindrić, Associate,
Middle East Urbanism Leader

Arid environments are characterised by a natural scarcity of fresh water and precipitation. Currently, arid environments cover over 30% of the world's land surface, a percentage that is set to increase with climate change in the coming century. Cities in these regions face complex challenges such as water scarcity, inadequate infrastructure, rapidly growing populations, and impacts on public health from the effects of urban heat islands.

Yet most cities in arid environments are still planned and designed based on a global city making paradigm established during the middle parts of the 20th century. This one-size-fits-all approach, characterised by private car ownership and separate land uses connected by highway networks, fails to respond to specific climatic contexts and needs.

Planners, engineers and decision makers working in arid environments require climate appropriate design solutions to create sustainable and liveable cities. Future responses must be tailored to specific social, economic, environmental and political conditions, combining the best of new technology with locally adapted solutions.

This report capitalises on Arup's pioneering work on projects in arid environments, mainly the Arabian Gulf region, southern Africa and the American Southwest. It contains ideas and case studies from around the world that showcase best practices in sustainable design for arid cities.

Cities Alive: Rethinking Cities in Arid Environments proposes a strategic re-think of how we plan and design cities in arid regions. Unprecedented advances in technological innovation have opened up new opportunities to develop arid cities in a more sustainable and resilient way. At the same time, there are lessons that can be learned from arid cities that have developed distinct design vernaculars over millennia.

At the heart of the report sit three key principles to shape the next century of city building in arid environments:

Learn from the past and build on locally adapted climate-specific design solutions

Invest in green and blue infrastructure that is designed to work with local environmental and ecological systems

Design intelligent buildings and public spaces that can meet the needs of people in changing climate

▲ Msheireb Downtown Doha in Qatar

The imperative for cities in arid environments to plan, design and build more sustainable and resilient cities is clear. Adopting strategies that combine technological innovation with locally adapted and climatically appropriate solutions can help cities and communities mitigate the effects of climate change and provide positive long-term social, environmental and economic benefits.

The report explores climate specific design strategies for arid cities together with case studies and reflections from leading practitioners who have experience implementing solutions. They include strategies for effective groundwater management, pioneering landscape and irrigation techniques, recommendations for innovative buildings and materials and sustainable urban design approaches.

"In the Arabian Gulf [...], climate change, in the absence of significant mitigation, is likely to severely impact human habitability in the future."

Jeremy S Pal and Elfatih A B Eltahir[1]

The strategies, case studies and reflections in the report were generated through a series of global workshops, have been grouped under three scales reflecting the wide ranging expertise of the contributors. The report is structured by level of detail from cities, to public spaces, to individual buildings.

The report concludes with a list of possible actions on how the strategies, case studies and reflections can help shape the necessary re-design and development of cities in arid environments; making them more sustainable, healthier and better places to live.

The actions are a first step and are intended to trigger debate and exchange between arid cities.

▼ The model arid city

Cities

Preventing urban sprawl
Aquifer recharge
Attitudes to recycled water
Active lifestyles
Policy and fiscal incentives
Development densities
Green investments
Decentralised infrastructure
Groundwater management
Social interaction
Improved air quality
Civic pride

Public Spaces

Designing for walking
Future-proofing mobility
Efficient irrigation
Nocturnal lighting
Xeriscaped landscapes
Having fun
Sustainable drainage
Inclusive spaces
Permeable pavements
Addressing intrusion
Productive landscapes
Complete streets

Buildings

Responsive building façades
Biodiversity
Localised vernacular
Microclimate
Dew harvesting
Greening buildings
Building orientation
Green and blue roofs
Indoor-outdoor spaces
Innovation in cooling
Recycling water
Low-tech innovation

“A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because […] a new generation grows up that is familiar with it.”

Max Plank

Context

What are arid environments?

Arid environments are characterised by a natural scarcity of fresh water and/or precipitation. Just over 30% of the world's land surface is classified as arid, a figure that is set to increase with climate change.

Aridity is the result of the complex interplay between climate and geography, found in parts of the world where dry, descending air is prevalent, such as the subtopics. Arid zones are also found on the sheltered sides of major mountain ranges where 'rain shadows' are created, such as the Andes, and on dramatically-heated land surfaces far from major water bodies, such as inland Australia.

Although arid environments have typical characteristics, they can be very diverse in character and are often defined by the specific interplay of temperature (hot and cold) and rainfall. They have different flora and fauna, geography and geology, resulting in different forms of human settlement.

In the context of Cities Alive, arid environments should not fall under the restrictive term 'deserts' — technically speaking, most of the interior of Iceland, with its severe cold and wet climate, is uninhabitable volcanic desert.

Broadly speaking, arid environments can be subdivided into three zones: hyper-arid, arid and semi-arid.

Hyper-arid zones cover over 4% of the earth's surface, arid zones just under 15%, and semi-arid zones around 12%. Together, these account for almost a third of the planet's total land surface, which is likely to increase with climate change.

3 miles

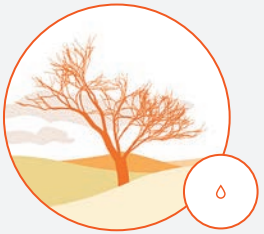
annual average distance that the climate is moving north in Europe and North America.[2]

15%

drop in rainfall since the 1970's impacting key food-growing regions in the global south are likely to experience more droughts.[3]

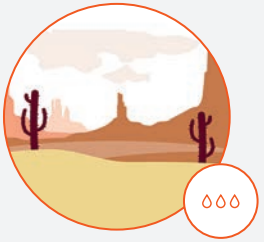
90%

average humidity is experienced during summer months in the arid cities along the Arabian Gulf shores.[4]



100mm
precipitation

Hyper-arid zones comprise extremely dry land, almost devoid of vegetation, apart from a few scattered shrubs. Annual rainfall is low, rarely exceeding 100mm, and irregular, sometime absent for years. Traditional human habitation is nomadic pastoralism, with no form of continuous settlement.



300mm
precipitation

Arid zones are varied landscapes, planted with sparse native vegetation, such as annual and perennial grasses, shrubs and small trees. Rainfall varies in regularity and ranges from 200mm to 300mm per annum. Human habitation is characterised by pastoralism and limited settlement, historically linked to irrigated farming land.

900mm
precipitation

Semi-arid zones have no typical land form, native vegetation includes a variety of species, such as grasses and grass-like plants, half-shrubs, shrubs and trees. Annual rainfall is more regular, reaching up to 900mm. This level of precipitation is able to support sustained agriculture and therefore substantial urban development.

Cities in arid environments

In arid environments, cities have stood at the forefront of urban innovation for millennia. The earliest urban settlements emerged between 4500 and 3500 BCE on the alluvial plains between the Tigris and Euphrates rivers. Despite, or potentially due to the challenging arid conditions, innovative irrigation, farming and building techniques adapted to the local climate and seasonal rains made this region hospitable for long term settlement.

The size and shape of arid cities has always been driven by environmental constraints such as the ability to manage fresh water resources for food production and public health. However, over the last 60 to 70 years, technological advances in water management, logistics and transportation systems, and crucially, air-conditioning, have allowed arid cities to grow exponentially.

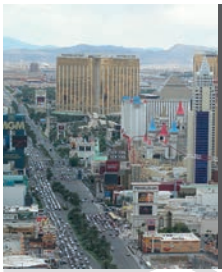
Today, the Arabian Gulf region and the American south-west are home to a number of cities that, up until a century ago, had no capability to support millions of inhabitants.

Cities like Las Vegas and Abu Dhabi could not support current population levels without innovations such as desalination technology, access to global food supply chains, climate controlled buildings, personal cars, and complex engineering projects such as the Hoover dam and Umm Al Nar power and desalination plant.

The drawback is that many of the same technological innovations that have enabled explosive growth and dramatic increases in quality of life are unsustainable and have resulted in new environmental challenges. These include climate change, desertification and degraded local habitats, water scarcity, public health issues related to air pollution and urban heat islands.

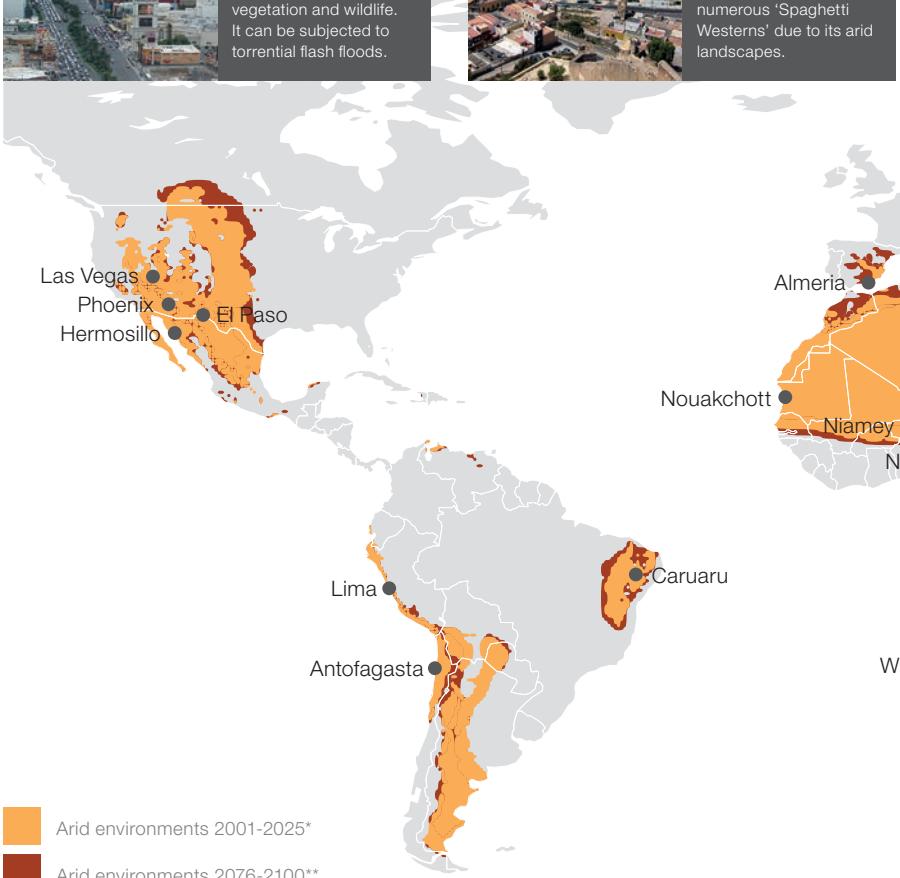
These challenges underscore the need to radically rethink the way cities in arid environments are planned and designed in the 21st century.

◀ The ever-expanding skyline of Riyadh, Capital of Saudi Arabia

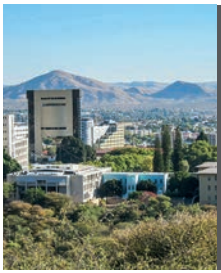


Las Vegas is situated in a basin of the Mojave Desert, surrounded by mountain ranges and had a population of only 25 in 1900. Much of the landscape is rocky and arid with desert vegetation and wildlife. It can be subjected to torrential flash floods.

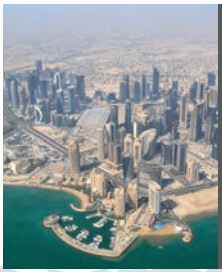
Almeria is a major city in Andalusia, south of Spain, and Europe's driest city. The city is Dependant on its food production, with 100,000 acres of greenhouses. It has been the set of numerous 'Spaghetti Westerns' due to its arid landscapes.



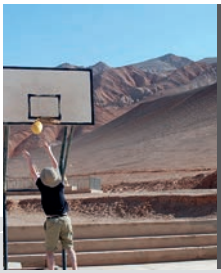
Antofagasta is a port city in northern Chile. The city is a centre for mining and has the countries highest GDP. It has little vegetation because it is situated in the Atacama Desert, which is the world's driest desert.



Windhoek is the capital of Namibia. Expanding the town area has – apart from financial restrictions – proven to be challenging due to its geographical location. Mountainous areas surround the majority of the town, which make land development costly.

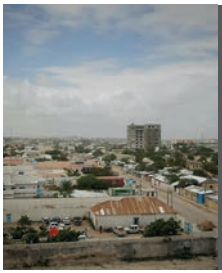


Doha is located on the central-east portion of Qatar. Doha is the capital and main center of this highly urbanised nation. Land reclamation off the coast has added 400 hectares of land. It has been among the world's fastest growing cities for the past three decades.

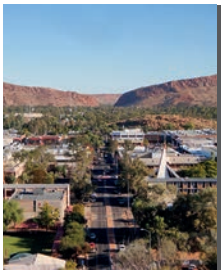


Turpan is located in the east of Xinjiang, People's Republic of China and has a harsh, drastic, cold desert climate, with very hot and long summers, and very cold but short winters, and brief spring and autumn in between. The oasis city is China's main grape cultivator.

*based on Köppen-Geiger classifications of Arid Climates
**based on A1FI Scenario



Mogadishu is the capital of Somalia, situated on the Indian Ocean coast of the Horn of Africa. Political instability has blighted Somalia for years, yet the natural population growth there is one of the highest globally.



Alice Springs lays in the Northern Territory of Australia. The surrounding region is known as Central Australia, or the Red Centre, an arid environment consisting of several deserts. Through the city runs the usually dry Todd River.

Key challenges for arid cities

Hyper-arid, arid and semi-arid zones cover currently over 30% of the earth's land surface and are home to more than a third of the world's population. With climate change predicted to result in net global temperature increases in the coming century, arid zones are also expected to expand.[5]

Already vulnerable to water scarcity, the impacts of climate change are expected to be more severe in arid regions than in other parts of the world. Climate change will disrupt the frequency and intensity of rainfall in arid regions, with some areas seeing less overall precipitation and others experiencing more unpredictable rainfall patterns.

The effects of climate change are already starting to be felt. In the United States, scientists have recorded that flora and fauna are creeping northward at an average rate of 3 miles per year due to the warming temperatures. In Australia, cities like Adelaide in the southern and eastern parts of the country experienced a crippling drought that lasted nearly a decade from 2001 to 2009.

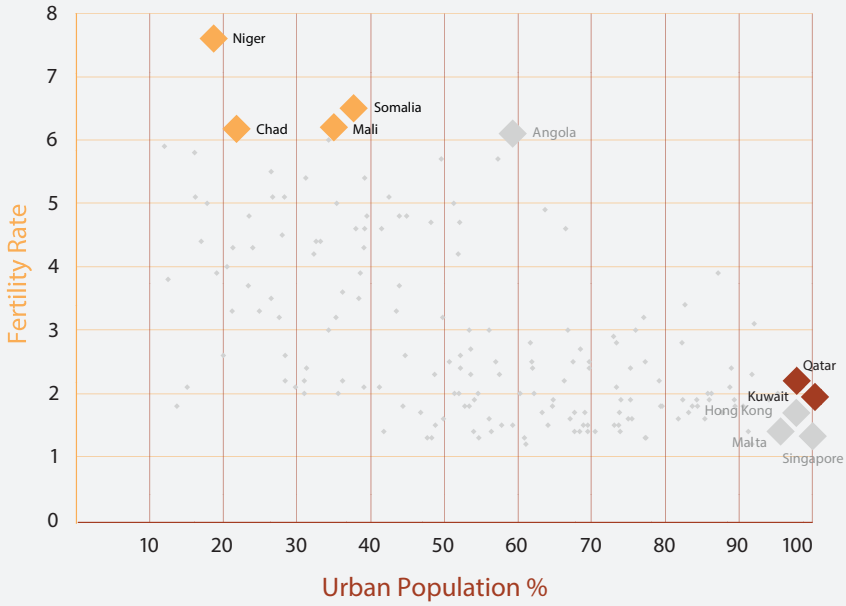
These changes are putting additional stresses on infrastructure and water management systems, compromising food production, putting people's lives at risk and destabilising national economies. At the global level, the cost in terms of lost GDP from the impacts of climate change have been estimated to be US$44 trillion dollars by the year 2060.[6]

Adding to this challenge, cities in arid environments are expected to experience the highest rates of natural population growth and urbanisation in the coming century. These future arid mega cities in underdeveloped areas such as the Sahel zone will need tailored responses to help them address challenges.

If status quo is to continue, it will result in cities that produce larger amounts of pollution and create waste heat from human activity. Such unsustainable cities would place increased demands on precious water resources and create less liveable cities.

Fertility Rate	7.6	6.5	6.2	6.2	6.1
	Niger	Somalia	Chad	Mali	Angola

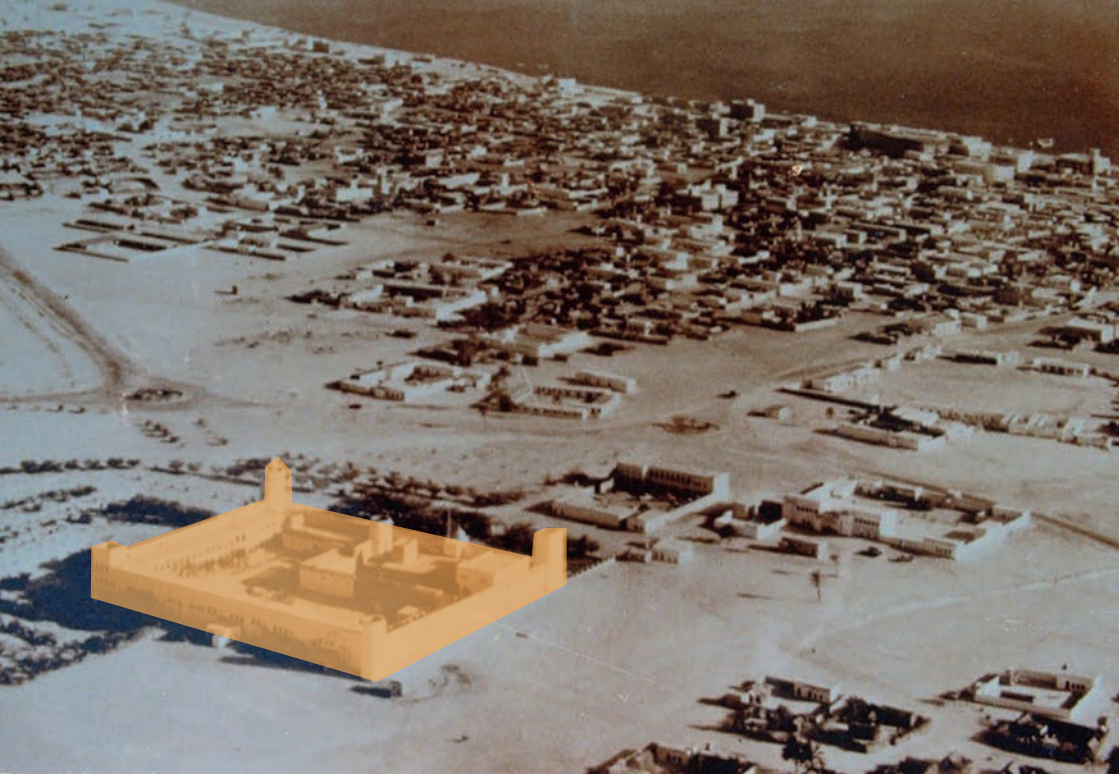
Fertility Rate defined as average number of children a woman has in her child-bearing years.[7]



Urban Population	100	98.8	98.3	97.8	95.4
	Singapore	Qatar	Kuwait	Hong Kong	Malta

Urban Population % defined as ratio of population living in cities and towns versus rural areas.[8]

The megatrend towards increasing urbanisation, paired with persistently high birth rates will inevitably lead to enormous urban growth in arid environments as varied as Mali and Afghanistan. Niamey, for example, the capital city of Niger is set to grow from 1.3 Million today to 56 million by 2100 by some projections.[9]



The case for taking action to mitigate against and adapt to the impacts of climate change in arid regions appears a straightforward choice to make. However, for arid cities that have mushroomed over the last sixty years, current infrastructure and city making methods are not explicitly designed to meet this challenge.

Many cities in arid regions lack infrastructure that is regionally specific and locally adapted to meet the specific needs of the local environment, let alone the challenges of a changing climate. This is because many cities in arid regions were planned and designed based on a global city making paradigm established back in the 1950s.

This global paradigm, based on car-centric design, separated land uses, speculative development and homogenised design has resulted in sprawling arid cities. The availability of vast tracts of cheap land, or land with limited economic value in arid regions, has helped fuel unsustainable urban development in formerly inhospitable environments.

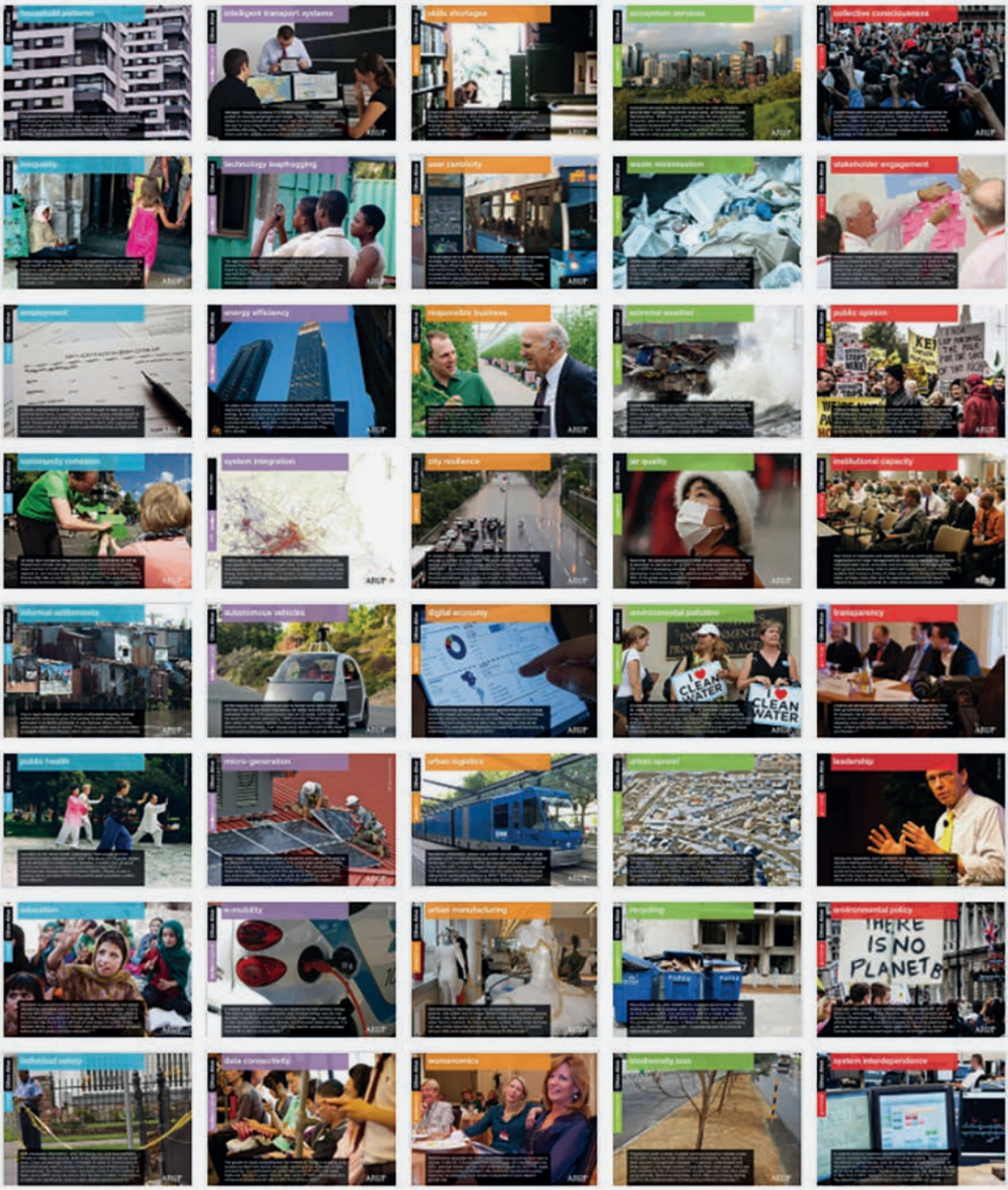
Nowhere is this more evident than in cities of the Arabian Gulf like Dubai, where the combination of cheap land and connections to global transport and utility networks established since the 1980s has sparked rampant urbanisation on an unprecedented scale. Another important, if under looked, factor is the role of central air-conditioning which has made formerly inhospitably hot regions around the world liveable. It would be unfathomable to think of Dubai or any other large arid city playing host to corporate head offices or glass skyscrapers without air conditioning.

The result of this globalised city making paradigm are arid cities that are sprawling, standardised and enabled by unsustainable infrastructure that are not responsive to local climatic conditions. Great swaths of cities as disparate as Doha, Phoenix and Ürümqi have similar skylines, share the architectural styles and infrastructural systems as cities in more temperate and northern climates.

This one-size-fits all approach to city making creates urban environments that are not only homogenous and poorly adapted to local conditions, they are unhealthy for people and the environment. The use of heat-trapping building materials such as glass, steel, concrete and asphalt exacerbate the urban heat island effect, trapping atmospheric pollutants and damaging public health. The scarcity of water, and sometimes high temperatures, is also a ready-made excuse to not provide citizens with the quality public realm they would find elsewhere.

Taken altogether, the challenges facing cities in arid environments constitute a crisis that needs addressing. A rethink of arid city components, from entire neighbourhoods to individual buildings, squares and streets, will require new planning strategies, design approaches and changes to individuals' behaviours and attitudes. This report outlines strategies for moving forward.

◀ Abu Dhabi City circa 1960 and now - Qasar Al Hosn (the square fort in the centre of both images) was once a dominant built structure using local materials, and is now dwarfed by the glass tower skyline.



CASE STUDY 01

100 Issues shaping the Future of Cities

Arup's Cities Alive: 100 issues shaping future cities, are a deck of cards that will help stakeholders at all levels — citizens, planners, and officials – to prioritise and explore issues shaping the future of their city. The trends have been collected and summarised in order to facilitate conversations, enhance understanding, support decision making, and help cities develop new ideas and solutions.

Necessary rethink

"Many of the received models of modern architecture and planning owe their ultimate origin to the [north-Atlantic] building code and public health reform movements of the second half of the 19th century"

Kenneth Frampton

Responding to this challenge, in 2017, Arup initiated a series of workshops anchored around our Middle East offices to explore how cities in arid environments are adapting to change. The workshops brought together global Arup contributors from the worlds of planning, engineering, landscape architecture and architecture to discuss issues and best practices for sustainable design in this region.

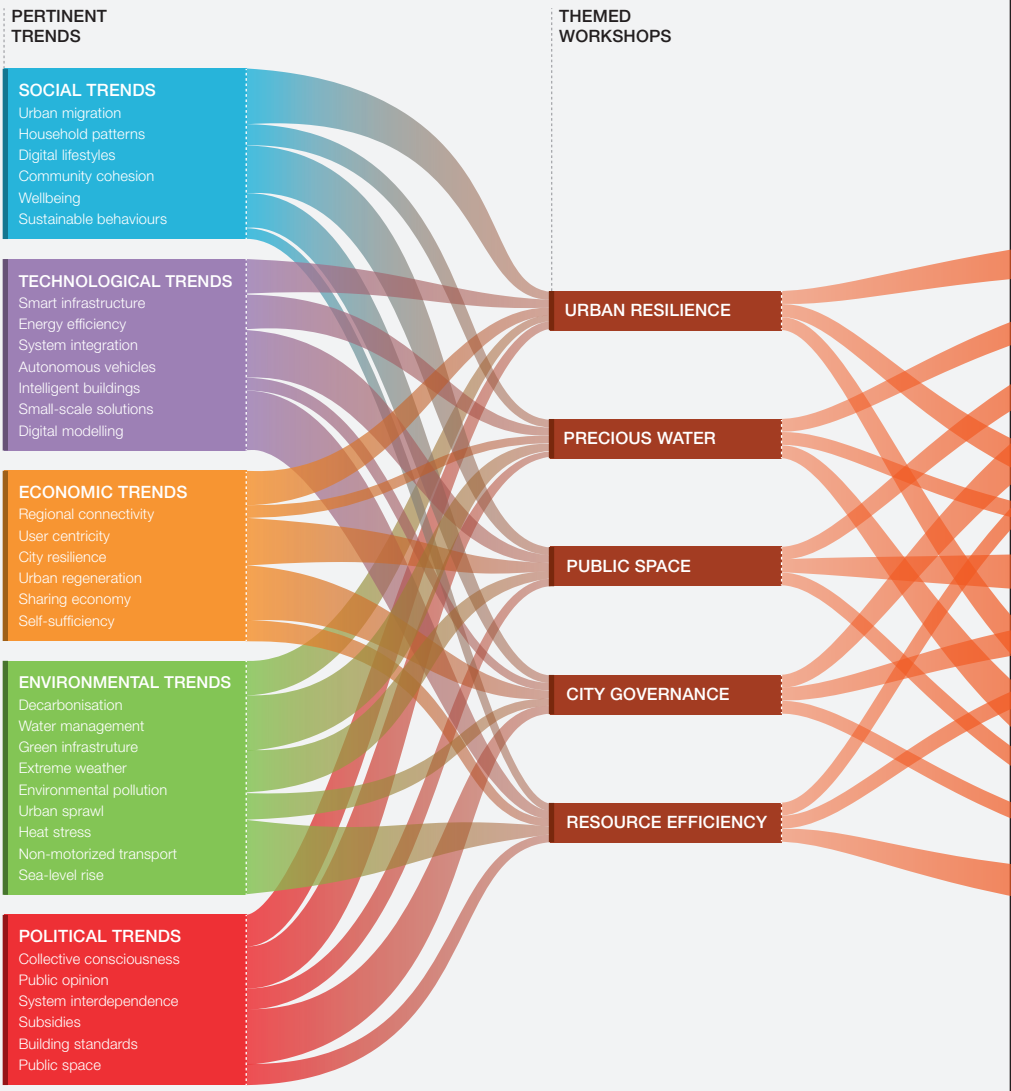
The workshops were organised around five key themes of precious water, urban resilience, public space, resource efficiency and city governance. These themes were explored in depth using *Arup's Cities Alive: 100 Issues Shaping the Future of Cities* foresight tool to stimulate conversation about the most pertinent social, technological, environmental, economic and political trends driving change.

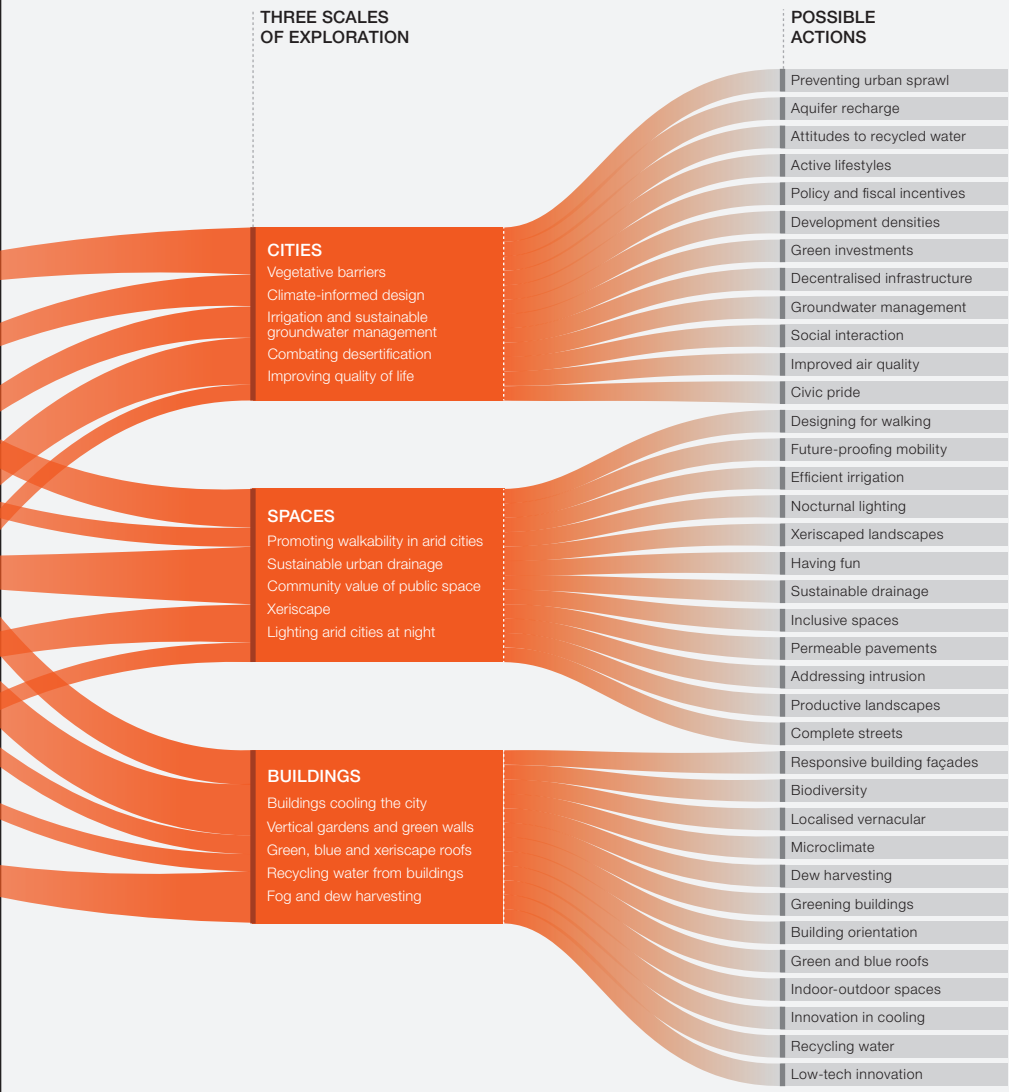
Over the course of these workshops, it became clear that the scale of the challenge was global in nature, with arid environments found on every continent of the world. It also became clear that sustainable design solutions from more temperate climates could not simply be imported and applied wholesale, underlining the need to support locally adapted solutions.

It was in this spirit that this publication in the Cities Alive series was born. This report brings together recommendations, objectives and techniques relevant to arid cities contained in previous reports, such as *Rethinking Green Infrastructure, Rethinking the Shades of Night, Green Building Envelope and Towards a Walking World*, combined with the knowledge of global design professionals.

Because of the scale of the challenge, and the need for cross-disciplinary solutions, it was decided that the report should be structured according to scale (cities, spaces, buildings) rather than grouping ideas according to theme. Each scale contains a number of ideas and specific strategies that touch on a number of themes such as water and resource management or quality of life.

Thought process




THREE SCALES OF EXPLORATION
POSSIBLE ACTIONS
CITIES
Vegetative barriers
Climate-informed design
Irrigation and sustainable groundwater management
Combating desertification
Improving quality of life
SPACES
Promoting walkability in arid cities
Sustainable urban drainage
Community value of public space
Xeriscape
Lighting arid cities at night
BUILDINGS
Buildings cooling the city
Vertical gardens and green walls
Green, blue and xeriscape roofs
Recycling water from buildings
Fog and dew harvesting
Preventing urban sprawl
Aquifer recharge
Attitudes to recycled water
Active lifestyles
Policy and fiscal incentives
Development densities
Green investments
Decentralised infrastructure
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Permeable pavements
Addressing intrusion
Productive landscapes
Complete streets
Responsive building façades
Biodiversity
Localised vernacular
Microclimate
Dew harvesting
Greening buildings
Building orientation
Green and blue roofs
Indoor-outdoor spaces
Innovation in cooling
Recycling water
Low-tech innovation

What are Urban Heat Islands?

"The world is warming and more people live in cities than ever before. While these two facts might seem unrelated, they have an important connection due to a phenomenon called the Urban Heat Island." [10]

Met Office, UK

When cities exhibit higher temperatures than the rural areas that surround them, particularly at night, this is known as the Urban Heat Island (UHI) effect. The phenomenon is the result of a combination of factors, primarily heat generated from large swathes of impermeable and non-reflective surfaces, such as asphalt and concrete, that absorb and store heat.

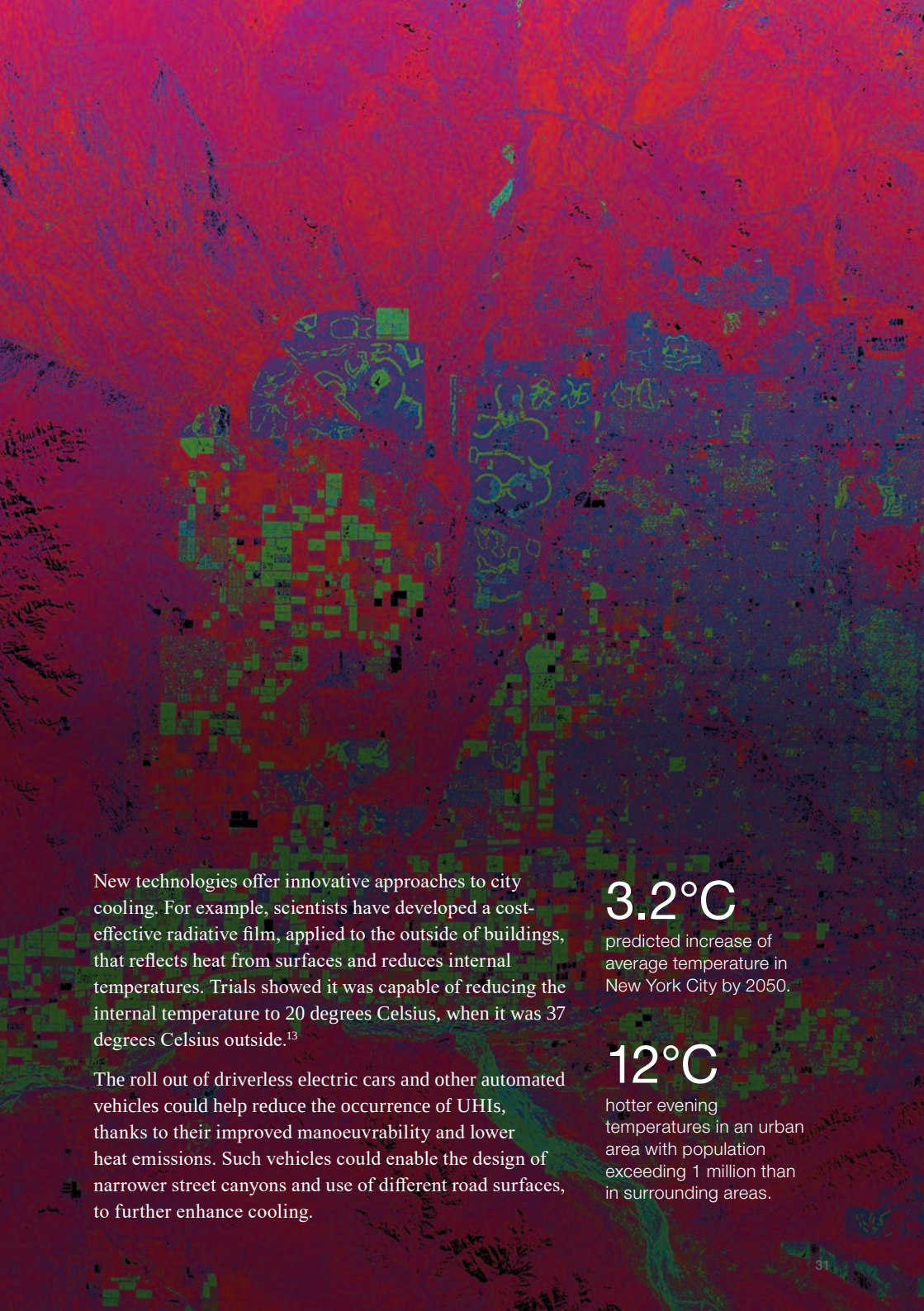
Additional heat is generated by urban activities, such as combustion engines in vehicles, and exacerbated by the way cities are planned and developed. There is a direct correlation between UHI and population densities.[11]

Cities in arid environments suffer from the effects of UHIs, with negative impacts on the environment, people and economies. Heat islands are known to increase water use and energy consumption through increased demand on air conditioning, increasing air pollution and impacting public health and quality of life.[12] Heat-related illnesses and mortality are of particular concern for vulnerable groups such as children and the elderly.

There are methods to mitigate the impact of heat islands through the design of the built environment, both in new developments or regeneration projects.

Simple and well-established practices include measures to minimise hardscape and incorporate more natural and permeable surfaces. Green roofs and walls, porous paving, and switching the orientation of buildings, or better yet entire city grids, can reduce the amount of heat absorbed.

▶ Heat map of Phoenix, Arizona



New technologies offer innovative approaches to city cooling. For example, scientists have developed a cost-effective radiative film, applied to the outside of buildings, that reflects heat from surfaces and reduces internal temperatures. Trials showed it was capable of reducing the internal temperature to 20 degrees Celsius, when it was 37 degrees Celsius outside.[13]

The roll out of driverless electric cars and other automated vehicles could help reduce the occurrence of UHIs, thanks to their improved manoeuvrability and lower heat emissions. Such vehicles could enable the design of narrower street canyons and use of different road surfaces, to further enhance cooling.

3.2°C

predicted increase of average temperature in New York City by 2050.

12°C

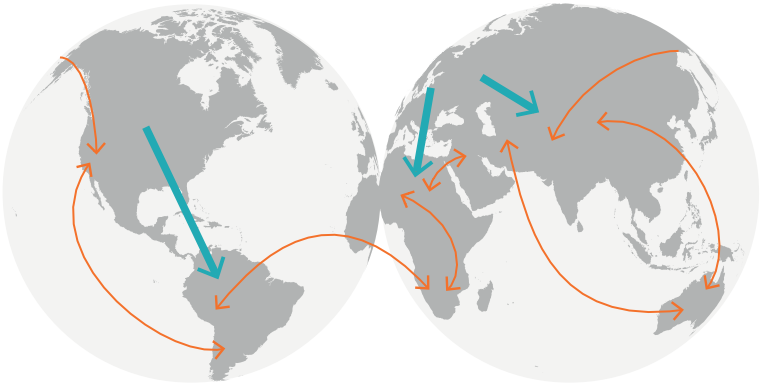
hotter evening temperatures in an urban area with population exceeding 1 million than in surrounding areas.

The way forward

Humans are at a critical moment in the history of their development where urbanisation and unprecedented technological innovation combined with traditional knowledge and building practices are converging to create new opportunities to design cities that work in cooperation with ecological systems.

Arid cities should be at the forefront of innovation in this field, and it is critical that they learn from each other.

Developed arid cities that have the means to experiment and establish best practices can provide a blueprint for less developed cities where the effects of climate change and mass urbanisation will be most severely felt.

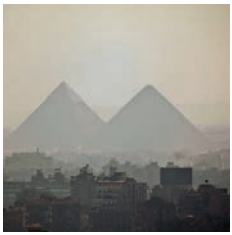


In recent years, the north-to-south export of expertise has been challenged by a south-to-south knowledge exchange in development aid, with a corresponding targeted improvement to the life of local populations. For cities in arid environments a similar exchange is needed.

This is the only way to achieve a paradigm shift towards more sustainable urban planning and design practices in arid cities. The era of a north-Atlantic expertise setting an ubiquitous global city making agenda must be replaced by arid cities establishing their own best practices and sharing climate appropriate design solutions.[14]

A key ambition for *Cities Alive: Rethinking Cities in Arid Environments* is to broker this exchange of ideas. Arup's global experience working on some of the most forward-looking projects in arid and water scarce region, combined with our expertise in sustainable infrastructure design and our commitment to shaping a better world, means we are uniquely positioned facilitate this conversation.

The report is structured to present best practices for sustainable design in arid environments at the scale of cities, spaces, and buildings. The best practices are presented with illustrated examples showing implementation as well as critical reflections from leading practitioners on the forefront of city making in arid regions around the world.



▲ Cairo is the world's most populous arid city.

▲ Dubai has evolved into a global Alpha + city.

▲ Niamey, like many sub-Saharan cities, is expected to grow exponentially in the future.

Beyond best practices, which are subject to change as technologies and circumstances evolve, the report proposes three guiding principles to inform the future of city making in arid regions.

Learn from the past and build on locally adapted climate-specific design solutions.

City making in arid environments needs to be adapted to meet the specific requirements of the local climate, while planning for future climate changes. A great deal can be learned from the traditional architectural vernacular of arid environments, which has often evolved in response to local conditions.

Invest in green and blue infrastructure that is designed to work with local environmental and ecological systems.

The integration of green and blue infrastructure into urban design can create healthier more socially cohesive and biodiverse urban environments with built-in resilience measures against climate change in the form of storm, flood, heat drought and pollution protection.

Design intelligent buildings and public spaces that can meet the needs of people in changing climate.

Technologies such as data monitoring, internet of things, and networked devices can help optimise the performance of buildings and public spaces. These technologies can also help city makers achieve energy efficiencies and provide intelligent insights into use and function to inform future designs.

Learning from the past, investing in green and blue infrastructure and embracing new technologies can help cities in arid regions design more responsively for an uncertain future. Being responsive to climate change and planning for its effects is not only needed to preserve the wellbeing of people and the environment, it also makes economic sense.

CASE STUDY 02
Msheireb, Doha, Qatar

There has been an encouraging trend in recent years to rediscover the traditional arid vernacular to help make arid cities more climate responsive. At the forefront of this approach is the major development of Msheireb (formerly known as the Heart of Doha), in Qatar.

Msheireb was conceived to preserve and regenerate the historical downtown of Doha. It blends traditional urban heritage and aesthetics with modern technology designed to respond to the local climate. The project's ambitions for sustainability and environmental responsiveness reflect the vision of Her Highness Sheikha Moza bint Nasser, who has played a major role in spearheading national and international development projects in Qatar.[15]

Strategic objectives of the project include a focus on sustainable design that consumes fewer resources, reduces the carbon footprint, generates less waste, and costs less to operate, as a direct result of efforts to manage the local climate. In addition, the development aims to reverse a trend for real estate development that encourages isolated and energy-intensive land use, urban sprawl, and over-reliance on the private car.

Msheireb is a blueprint for a contextually-relevant and sustainable urban form, where architectural lessons from history are aligned with the latest technological advancements. Lessons learnt from this approach, summed up by the development's catch-phrase, 'rooted in the past, whilst looking to the future', should extend beyond the Arabian Gulf and form part of city making paradigms for cities across the globe.

Water for a liveable City of Adelaide

Michelle English,
Sustainability at City of Adelaide

Like many arid regions, Australia's relationship with its climate is part of the cultural and historical landscape. The Adelaide plains are home to the Kaurna people, who understood the importance of water and its cycles. Historically European settlers relationship with the Australian climate and environment was more antipathetic, with implications for our cities and environment.

Adelaide's annual rainfall just edges the threshold to being semi-arid, but that might need to be adjusted due to climate change. The city's drought from 2001 to 2009 contributed to a shift in thinking in water management and security and Adelaide's long held reliance on the water supply from the River Murray, as did the recognition that climate change would reproduce these conditions.

Now, we increasingly view our climate through the prism of liveability and well-being and the relationship between climate and the social, health and well-being values underpinned by water.

Adelaide's previous responses to drought involved introducing water restrictions on irrigation of public green areas. As recognition of the social value of green infrastructure grows, so does the value of the contribution of water to these uses.

The drought was a catalyst for the construction of a desalination plant, several aquifer storage and recovery (ASR) stormwater recycling schemes and other wastewater recycling schemes. These supply water to large areas of green infrastructure, such as the Adelaide Park Lands, which are supplied by the Glenelg Adelaide Pipeline Recycled Water scheme.

Green infrastructure is a key focus in our approach to integrated urban design and water management. The South Australian Government's 30-year Plan and the City of Adelaide's strategic plan both outline ambitious targets to increase green infrastructure. The City of Adelaide is increasing investment in urban greening and has set ambitious targets.

▲ Adelaide receives just enough annual precipitation to avoid being classified as arid

We aim to increase greening in the city area by 100,000m², including 1,000 new trees, by 2020 and to increase canopy cover from 14% to 25% in the CBD and 28 to 40% in North Adelaide by 2040.

Urban cooling trials around Adelaide have shown that a temperature reduction of over 4 degrees Celsius is achievable during hot periods through targeted irrigation of open space. In dense urban environments integrating cooler larger open space areas with street trees, green walls and other forms of smaller scale green infrastructure that can be retrofitted into the urban form will be the key to maximising urban cooling outcomes.

Recycled water is climate independent and stormwater is climate dependent, and while the use of aquifer storage has enabled stormwater to become more reliable, future integration of recycled water and stormwater schemes will provide a more holistic and robust "alternative" water supply for non-potable uses. Using these water sources also reduces the environmental impacts from discharge to receiving marine and river environments.

Understanding and quantification of the benefits of using recycled water and stormwater to support green infrastructure has changed the economic discussion regarding water management. The recognition of the benefits by government, private sector, researchers and the general community has been the catalyst for the development of cross-sectoral relationships that are advancing these new approaches and building resilience to the challenges faced by Adelaide and cities in arid environments.

“You could not have evolved a complex system like a city or an organism without the emergence of laws that constrain their behavior in order for them to be resilient.”

Geoffrey West

Cities


WAL★MART

Cities introduction

Jerome Frost OBE,
Arup Global Planning & Cities Leader

In our mission to shape a better world we must shape better cities. It is increasingly cities, rather than national governments, that have the power to tackle climate change, drive the global economy, deliver prosperity and alleviate poverty.

The global rise of social media and the expansion of the middle classes have given urban citizens unprecedented power to choose where they live, work and invest and demand a better quality of life. Therefore, as the world continues to urbanise and cities increasingly compete with each other, it is the quality of life experienced by their populations that will be a major determinant of the future direction of the planet.

Cities in arid environments have existed for millennia, but urban and rural populations in these environments have experienced more rapid growth than anywhere else in recent years.

Arid environments are home to some of the world's most and least urbanised nations. From Kuwait and Qatar (both 99% urbanised), to Chad, Niger and South Sudan (all less than 20% urbanised). All are managing intense population growth as the threat of climate change, more extreme weather and limited access to natural resources increases.

For these cities to prosper they must address these challenges whilst creating the quality of life that allows them to compete globally. For many decades now Arup has combined its knowledge of strategic development, planning, finance, economics, design, engineering and implementation to deliver some of the most transformational projects across the globe.

In this document, we are pleased to share our knowledge, experience and research insight into cities in arid environments.

◀ Car-based, urban sprawl in Phoenix, Arizona

Cities are already leading the way

Mandy Ikert, C40,
Director of Water and Adaptation

The effects of climate disruption are already being felt in the great cities of the world, from hurricanes in New Orleans and New York, floods in Paris, Houston and Montreal, deadly heatwaves in Sydney, to toxic air pollution in Beijing and New Delhi. For cities in arid environments increased temperatures and even scarcer water sources will be dramatic.

The cost of inaction is staggering. Unless preventative action is taken, climate change-related natural disasters have been estimated to put 1.3 billion people at risk by 2050 and destroy assets worth $158 trillion — which is double the annual productive output of the world.[16] This explains why more than 190 nations decided to sign the Paris Agreement on Climate Change in 2015.

C40 is a network of the world's megacities committed to addressing climate change and doing what needs to be done to implement the Paris Agreement. In late 2016, C40 in collaboration with Arup released Deadline 2020, the first significant route map for achieving the Paris Agreement. This report outlines the pace, scale and prioritisation of action needed by C40 member cities over the next 5 years and beyond to support the implementation of the Paris Agreement.

C40 mayors on every continent understand the evidence and urgency of the climate crisis and importantly recognise the economic potential in shifting towards a greener future. Acting both locally and collaboratively, C40 cities are having a meaningful global impact in reducing both greenhouse gas emission and climate risks.

In this context, cities in the arid environment are poised to leverage their long history of adaptability and innovation

▲ C40 Dubai Adaptation Conference

in dealing with harsh climate conditions. In Early 2016, the City of Dubai hosted C40's first Adaptation Conference. The conference brought together 48 C40 cities from across the world, as well as representatives of the Government of Dubai. They shared their ideas, knowledge and experiences on the impact of climate change on cities and how to adapt to the conditions climate change brings.

At the conference Akel Biltaji, Mayor of Amman, and H.E. Abdulla Al Shaibani, Secretary General of the Executive Council of Dubai, delivered clear messages about the priority they place on climate change adaptation and their commitment to implementing and delivering innovative climate solutions. Like the Secretary General and Mayor Biltaji, C40 Mayors understand that the health and wellbeing of their people and economies are at stake, and the risks of inaction are too great to ignore.

This is why sharing experiences and expertise from today's cities in arid environments will be critical for those of tomorrow. C40 and our member cities are determined to create resilient cities, prepared for whatever our future climate will be.

Vegetative barriers

The famous 20th century botanist André Aubréville coined the term ‘desertification’ and noted that “the desert always menaces”, a sentiment that applies in particular to cities in arid environments.[17]

Belts of trees, planted as structural elements in cities can offer protection from harsh climatic conditions, as well as define the public and private spheres of urban life.

Trees are a crucial component in city making; they offer environmental and health benefits, provide recreational value, and aid in city legibility. Cities around the world make use of structured tree planting as a design element. For example, the vitality of Barcelona’s famous La Rambla boulevard would be hard to imagine without the large, leafy trees that line the avenue and allow street life to flourish, even in the intense midday heat.

Inhospitable climates with burning sunlight and dust clouds, generated by the dry earth, do not readily promote active street life. As a result, local communities have evolved a rich tradition of using trees to provide shelter and protection for public life. Trees can have a positive effect on thermal comfort and environmental quality, shielding building façades and streets from scorching sunlight, and acting as a ground filter for surface runoff water.[18]

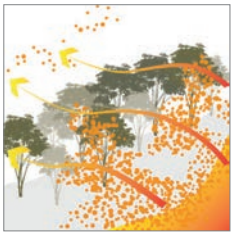
▼ Some of the 20 million trees in Abu Dhabi

Tree planting has become more ambitious in recent years, used by some regions to form large scale natural walls that define the urban edge and act as barrier to prevent the encroachment of the desert.

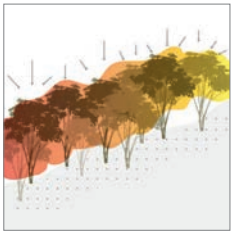
Notable examples include the planting of millions of trees in northern China to tame dust storms from the Gobi Desert. A multi-national project in Africa was set up to hold back the drought-ridden Sahel region by planting at times 14km wide natural barrier that dissects the continent, from east to west. It has been described as “the largest feat of horticulture in human history”.[19]

These projects can teach cities a great deal, such as the need to plant multiple species to make afforestation efforts more resilient. The scale and scope of such efforts requires centralised, citywide funding, and commitment and support from cities and their inhabitants, who will have to implement and care for the habitats.

Proponents of green city walls often cite environmental benefits and the potential for climate improvement to help justify large scale collective action and public investment. Similar to man-made urban infrastructure, large scale green walls can promote job creation and deliver knock-on benefits, such as mitigating the urban heat island effect, providing natural amenity space or expanding the green economy.



▲ Dust particle filtration



▲ Carbon sequestration and soil enrichment

▲ Cooling of air (on an urban scale+)

CASE STUDY 03

Shibam Hadhramaut, Shibam, Yemen

Shibam in Yemen is a UNESCO World Heritage Site, often referred to as the oldest skyscraper city. The origins of the city date back over 1,700 years, with the majority of the currently standing four to eight story buildings dating back to the early 16th century when the city was rebuilt after devastating floods.

Shibam is one the earliest cities in arid environments to be built on a strict grid, and whilst the tall towers provided safety from attackers, they also provided shelter from the harsh climate found on the edge of the Empty Quarter.

The vernacular provided residents with built form that is highly adapted to local climates and materiality, using locally available building materials and minimising window openings for example. While Shibam and other historic cities of this region are often copied for their romanticised values, the true qualities are lost in pastiche features, rather than the application of old planning and design principles coupled with appropriate modern material and technologies. [20]

Climate-informed design

Designing comfortable thermal environments in arid cities is becoming more of a challenge as we move away from the conventional concept of closed air conditioned ‘boxes’ and towards more sustainable low-energy design. Increasing city populations are creating an increasing need to incorporate pleasant outdoor spaces that can be used throughout the year and this increases the climatic challenge.

That said the climate should always be the starting point for the successful planning and design of external public space. And it should be remembered that arid city environments are not necessarily hot and dry at all times. For example, climate analysis for Madinat Al Irfan, a mixed use downtown development in Oman, revealed that the winter period is relatively mild, and therefore outdoor thermal comfort can be achieved using passive measures only.

The most important factors affecting thermal comfort in hot climates are exposure to the sun, humidity and air movement. By examining each of these factors and their relationship to the existing site and design it is possible to identify opportunities and drive key decisions early in planning and design processes.

During the more critical hot-dry period, the first priority should be to provide effective shading, which has the biggest impact on comfort. The annual position of the sun must be assessed to determine how shading can be optimised through street orientation and massing. Equally ensuring that street orientation and massing enable winds to penetrate spaces will further improve the conditions.

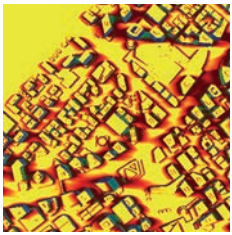
At Madinat Al Irfan, north-south oriented streets were designed as wider avenues for pedestrians, while sun-exposed streets, aligned east-west, were kept narrow and dense to increase shade. Climate analysis revealed the opportunity to use local winds to encourage air movement through the streets.

Advances in computing make it simpler to take advantage of this knowledge and implement passive systems in new builds or retrofits. Progressive numerical analysis and simulation tools give a more comprehensive understanding of the interaction between climate, site and design. Computational fluid dynamic analysis can simulate the wind flow patterns across cities; solar analysis can determine how heat conditions vary, identifying favourable conditions or hot areas where design intervention may be required.[21]

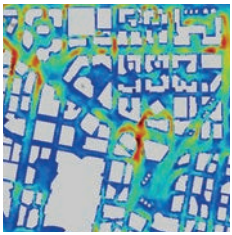
Extreme arid environments place severe limitations on design ambitions, in which case good design practice alone will not guarantee tolerable conditions year-round. Active systems, such as mechanical cooling air systems and water features, consume energy and water, and should be used cautiously and positioned where for maximum effect in key arid city locations.

It is worth remembering that intermediate design options exist, between purely passive measures, like solar shading, and purely active measures. For example, there may be potential to create semi air-conditioned spaces, for the external design. Alternatively, public spaces could utilise space within some buildings to mutually gain the benefit of air conditioning through the space. This approach would provide valuable areas of respite within the public realm within hot arid cities that positively utilise existing cooling systems.

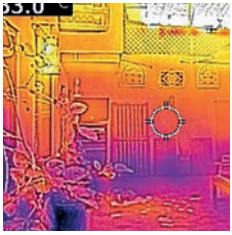
Climate change is expected to make arid environments hotter and drier in the future and some headline-grabbing research has stirred up concern.[22] Good design can make a profound difference to in our efforts to meet the challenges, especially when greater emphasis is placed on low energy and water efficient strategies.



▲ Thermal analysis



▲ Wind speed analysis



▲ Thermal image to assess existing condition

CASE STUDY 04

Seizing opportunity, Abu Dhabi, UAE

Water management is a major issue in cities in arid environments. The lack of predictability of major storms, or regularity of rain sometimes leads to miss or under investment. Whilst too much rain can cause severe damage and stresses on cities, thoughtful application of green and blue infrastructure principles also harbour opportunities beyond reducing cost and increasing resilience.

In this example children, seize the opportunity and are punting in a vacant development plot after a major downpour and demonstrate the intangible value of green and blue infrastructure.

Irrigation and sustainable groundwater management

Large scale irrigation is an important feature of many arid cities, essential for thriving crops and vegetation. However, without proper design and sustainable management, irrigation systems can have negative consequences for rising groundwater, flooding, construction and groundwater pollution.

Treated Sewage Effluent (TSE) is increasingly being utilised in arid cities to irrigate open green space, sports grounds and road corridors. TSE reduces the demand on desalinated water saving both money and energy needed to create potable water. TSE is increasingly being viewed as a valuable resource in many cities in the Arabian Gulf, with distribution managed at wastewater treatment plants and supply mains integrated across the city to support urban irrigation.

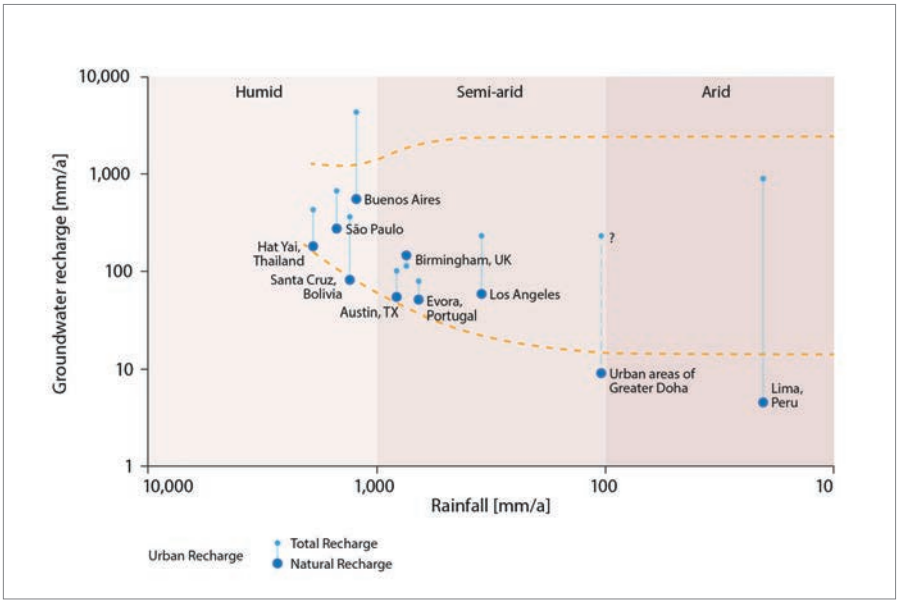
Figures on TSE used for irrigation are not widely published, but estimates indicate that it provides coverage of between 10 and 2,000mm per annum.[23]

TSE irrigation is not only beneficial for supporting vegetation, it can also help recharge depleted groundwater levels.

Over extraction of groundwater for human use combined with naturally occurring discharge into the sea, rivers and lakes can deplete groundwater levels. Whereas recharge through rainfall and artificial returns in the form of irrigation raise the groundwater level. The rate of change depends on the properties of the aquifer, the rate of leakage, and the regional groundwater regime.

In arid regions, naturally occurring groundwater recharge, calculated as rainfall minus evapotranspiration, ranges from 55mm to 110mm per annum. Excessive irrigation can boost recharge by up to 500%.

TSE irrigation can therefore support the naturally occurring hydrogeological cycle in arid cities, however close monitoring of groundwater levels is needed to avoid over-irrigation. The irrigation requirements of a given site vary depending on the environment, soil characteristics and types of species planted. Advanced sustainable irrigation systems need to take into account the rate of evapotranspiration and other conditions to achieve the right balance.



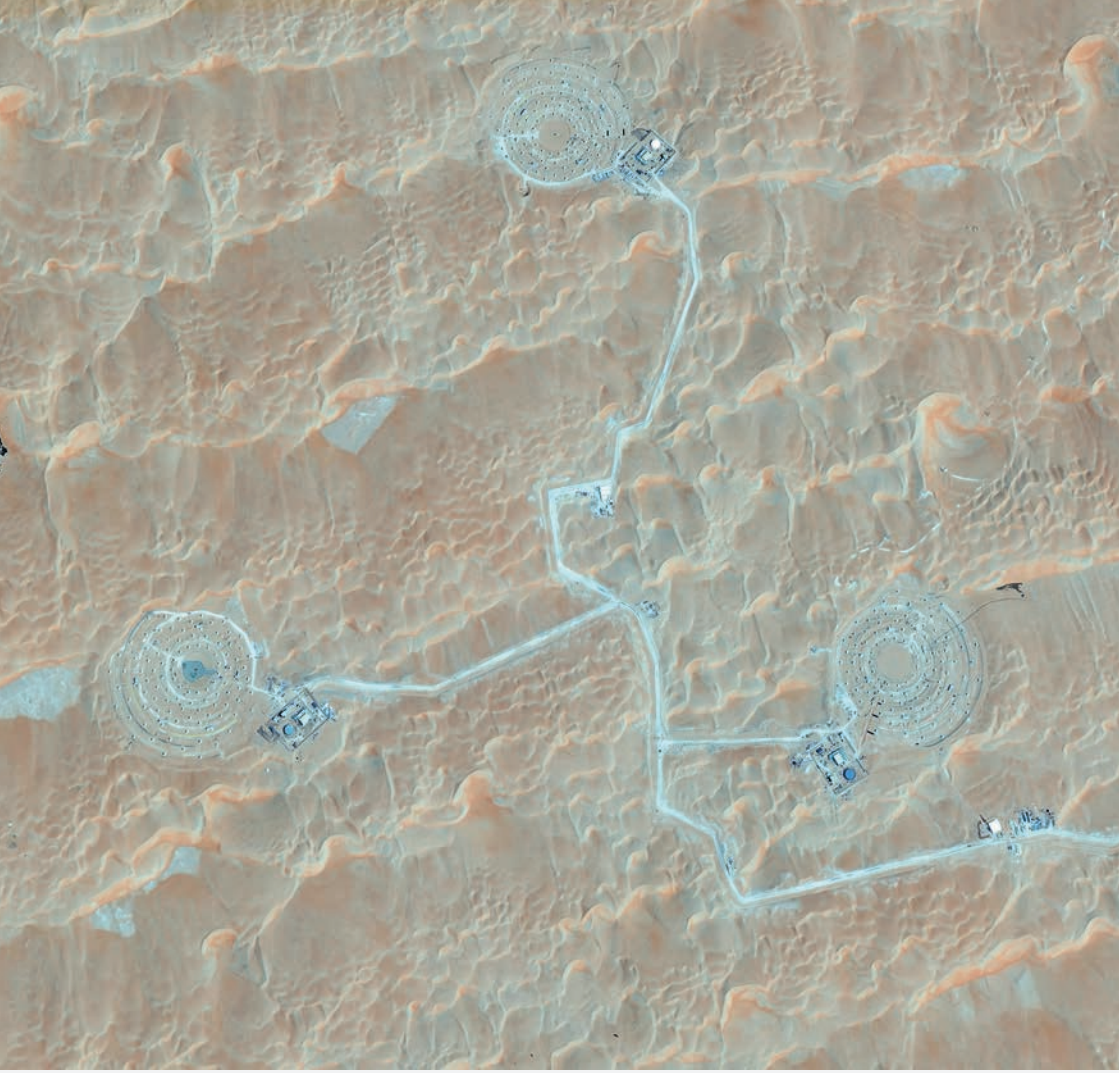
▲ Urban groundwater recharge in different cities (modified from Garcia-Fresca, 2004)

Over-irrigation can lead to a significant rise in the groundwater table and potential flooding. This is becoming a serious challenge in cities in arid environments where recharge is often high. For example, the Qatar National Strategy Development Plan 2011-2016 highlights problems related to rising groundwater levels in Doha, including negative impacts on construction and flooding risks to residences and infrastructure, and identifies the need for a proper management strategy.[24]

The most serious consequences of groundwater rises are flooded septic tanks, which spread untreated effluent into the aquifer, and submerged service mains, that can contaminate groundwater.

Sustainable water management should begin at design level with a strong conceptual understanding of the local hydrogeology. Infrastructure designs should account for the quantity of recharge generated by the development during operation and plans for mitigating negative impacts must be in place.

Groundwater rises can be managed by reducing the number of infiltrations or selecting vegetation species that require low levels of irrigation. Metering water usage to ensure sensible levels of irrigation, irrespective of the water source or water availability is another key action to take when groundwater rises become a challenge as might be draining saturated urban aquifers with wells.



CASE STUDY 05

Managed Aquifer Recharge (MAR) and Aquifer Storage and Recovery (ASR)

Managed Aquifer Recharge (MAR) and Aquifer Storage and Recovery (ASR) are used in arid regions to replenish groundwater resource and use the natural storage capacities. Various schemes are being developed globally to provide both potable and agricultural water supplies and create added resilience for times of water stresses.

The Liwa Strategic Water Reserve, some 200km south-east of Abu Dhabi city and the Arabian Gulf coast, is such a scheme that uses desalinated water and stores it in an ancient natural aquifer below the desert. The aquifer is recharged with surplus desalinated water from combined power / desalination plants that produce more water than is consumed during summer months when energy demand is highest.

This world's largest such project has an expandable capacity of over 20 billion litres. It provides a three month strategic reserve for the city and stores water that would have otherwise pumped back into the sea.

CASE STUDY 06

Wadi Hanifa, Riyadh, Saudi Arabia

This wadi south of Riyad has been dry except during flash floods. Since the construction of Riyadh's first large sewage treatment facility in 1982, a constant flow of sometimes poorly treated water has been created. In order to address issues with regard to public health further purification has been installed and a number of associated small lakes were created. Substantial sums were invested in the wadi's preservation that created dams to regulate water flow and the planting of vegetation to further purify the recycled water.

This excellent example of green and blue infrastructure, has become a popular recreational destination for the city which previously did not

feature any major public open spaces, and also a stop for migratory birds. In order to protect this newly created wetland and asset to the city, a green corridor, almost 100km, long has been designed.

Combating desertification

"It's preventing what American farmers did to cause the Dust Bowl in the 1930s."

Xian Xue, Professor,
Chinese Academy of Science[25]

Desertification is the process whereby land becomes increasingly arid and soils become degraded to the point where they can no longer support vegetation and wildlife. The emergence of deserts over millennia is a natural planetary phenomenon, however human factors such as the exploitation of forests, excessive grazing from livestock, and climate change are increasing the rate of desertification in arid regions.

Strategies to reverse this process by introducing 'green belts' and reforestation schemes are being implemented in arid regions around the world.

Among the most ambitious is China's Grain-for-Green programme which pays farmers to revert sloping or marginal farm land, prone to desertification, to plant trees. Launched in 1999, the programme has committed billions to fund the reforestation of 31.8 million hectares. In the last decade alone, China has spent more than $100 billion on reforestation efforts under this scheme.[26]

The Grain-for-Green scheme is one of the largest ecological restoration and rural development projects in the world, which has made a positive contribution to over 2.5 million households.[27] Land was successfully transformed into mixed forest, pasture, farm and recreational land, with more efficient water use. This resulted in new stockbreeding and tree crop production and the formation of secondary and tertiary industries. One participating county adopted a new model for afforestation that combines forestry and medicinal plants, helping preserve water and soil and generating higher economic returns.[28]

However, the good intentions of tree planting programmes can also lead to negative impacts. Counter-intuitively, reforestation can sometimes cause a decline in water resources, by reducing rainwater infiltration into the ground, an effect experienced in Northwest China.[29]

▲ A farmer in Western China inspects his functional transformed patch.

In addition, the transformation of land into conservation zones where farming or other productive uses are limited can result in a loss of vital income for residents.

On balance, combining the development of greenbelt areas around larger urban centres with initiatives like Grain-for-Green, many positive effects can be achieved for cities in arid environments. Wind speeds and air dust from adjacent arid areas can be reduced, creating better conditions for city dwellers. It can diversify of employment opportunities and economic activities, improve land conditions, reduce soil erosion, increase soil moisture and provide recreational and amenity space, maximising the return on the water investment made.

"The best time to plant a tree was 20 years ago."

Chinese proverb

CASE STUDY 07

Three-North Shelter Forest Program, Various Cities (Beijing, China shown)

The Three-North Shelter Forest Program or the Green Great Wall, is a series of human-planted forest shelterbelts. These strips of forests are primarily designed to hold back the eastward expansion of the Gobi Desert. Started in 1978, it is planned to be completed around 2050. It will have created some 4,500km of windbreaking forest strips that will provide protection from top soil erosion but also improve environmental quality of many Chinese cities, including Beijing.


博物院

Improving quality of life

"Healthy places make people feel comfortable and at ease, increasing social interaction and reducing anti-social behaviour, isolation and stress."

Landscape Institute, Public Health and Landscape (2013)

The harsh environmental conditions in arid cities have historically been a natural barrier to large scale urbanisation. However, in the last century, technological advances and economic activity, often related to resource extraction, have enabled many arid cities to thrive, resulting in huge population growth.

Arid cities that are built around resource extraction industries tend to have more transient populations, making it difficult to offer the same quality of life as those in more temperate zones. For example, several Australian mining towns have such inhospitable environments that few families settle long term. Even established former-mining towns, such as Mount Isa and Broken Hill, have higher male populations than the national average.[30]

However, recent trends suggest that arid cities are maturing and becoming more liveable, albeit some initially transient populations have never originally resolved to settling there. Many cities in the Arabian Gulf are no longer considered 'hardship postings' — a term used in the United States Diplomatic Service to describe a diplomatic post where living conditions are difficult due to climate, crime, health care or pollution.[31]

Critical to the maturing of arid cities is the provision of space where public life can take place outdoors more sustainably. However, creating liveable open spaces, streets and parks can be a challenge in arid climates, requiring specialised knowledge, irrigation systems and investment. For this reason, public space in developed arid cities often takes the form of air conditioned indoor shopping centres, airports and lobbies.

▲ Street improvement and tree planting project, Antofagasta, Chile

In Antofagasta, Chile's fifth largest city with the highest per capita GDP, the municipal government and local businesses have set up the CREO initiative to build a more green and vibrant public realm as a tool to attract and retain people.

A key aim of CREO is to invest in 'greening' initiatives in a city where annual rainfall is just 1mm and the high environmental and financial cost of water desalination, has historically prevented irrigation. CREO plans to use recycled water to irrigate large areas of vegetation, creating 75 hectares of greened public open space in the city. Water is treated via natural filtration and vegetation in a non-conventional method that reclaims wastewater from urban development and re-uses it as irrigation water within individual neighbourhoods.

Other strategies are helping overcome limitations on the capacity of Antofagasta's water infrastructure, due to rampant population growth and unplanned urbanisation. An innovative approach to micro sewage on site will help ease water demands in parts of the city where municipal infrastructure does not penetrate.

Greening Antofagasta with recycled water

Andres Letelier,
Executive Director CREO Antofagasta

The city of Antofagasta is the mining capital of Chile, located in the extreme north of Chile, with an approximate population of 400,000 inhabitants. Antofagasta's GDP per capita is approximately US$40,000 (Nominal in 2012), a figure equivalent to that of countries like South Korea or New Zealand. However, Antofagasta struggles to provide adequate green and public spaces for its residents.

Where the Chilean country average is approximately 4.1 m^2 per person of maintained green and public space, Antofagasta only has an average of 2.4 m^2 for each inhabitant, with a total of 86 hectares of vegetation coverage. All of these spaces are currently irrigated with desalinated potable water, which equates to an annual irrigation cost of US$1.5 million.

Antofagasta treats some 26 million m^3 of wastewater annually, of which 85% is pumped back out into the ocean. Only 15% of recycled wastewater is used in industrial processes. In Antofagasta, we recognised the enormous opportunity to use treated wastewater for irrigation of green and public spaces. Using recycled water would reduce the costs associated with irrigation, and facilitated an increase in trees and green coverage considerably in a city with only 2 to 4mm of annual rainfall (the lowest in any major city anywhere in the world).

The Recycled Water System of Antofagasta (SARA in Spanish) is a system that recovers, treats and reuses wastewater for irrigation of public Green Spaces. SARA not only helps increase the amount of green space in the city, it also helps preserve potable water and reduce the costs associated with desalination. The use of recycled wastewater in the irrigation of the city's green and public spaces will allow the municipality to save an estimated US$2.6million annually.

The proposed target for 2035 is to increase the vegetation coverage to 297 hectares, which would result in a provision of 9.2 m^2 per inhabitant, a value that would exceed national and international standards.

▲ Antofagasta is one of the driest cities on earth

Distributing autonomous wastewater treatment facilities across the city would bring water treatment to parts of the city not served by the citywide utility network. These autonomous plants use proven emerging technology, creating greenhouses within which wastewater is treatment in an efficient natural manner.

Each of the 10 proposed plants to be built by 2030 will be located in the upper parts of Antofagasta, also creating tree lined pedestrian friendly streets connecting the upper parts of the city with the central waterfront and its transportation infrastructure. Recycled water will also be used to irrigate adjacent new and existing parks and small green pocket squares, in the upper city and city centre.

The use of this recycled wastewater will underpin streets for people, improved by incorporating new tree planting, wider pavements, street furniture and lighting, and improved existing green and public spaces. By 2030 we expect to be re-using 5% of the wastewater and creating 20 linear km of tree lined streets and 30 hectares of Green Spaces for the people of Antofagasta.

CASE STUDY 08

Pilot: SARA Pisagua Plant

The autonomous greenhouse sewerage treatment plants present a series of technical and environmental advantages that were taken into account when selecting the system: it is a stable, safe and automatic process; it does not create odours; the chances of failure are minimal; the water produced is of high quality; and the plant creates a greenhouse interior space which can be visited by the general public and used as a community space for leisure and environmental education.

The pilot project will be built in a local center, to the north of central Antofagasta. In addition to the autonomous plant, a public and green area will be created in which the greenhouse facility is placed, and a 2.5 km route, with all vegetation to

be irrigated by the recycled water. All of the newly created spaces will be designed with the local communities, which have been engaged from the start of the project. The irrigation network will also facilitate the municipal plant nursery, which in turn will be opened to the public in 2018.

This first plant will represent a saving in irrigation of US$ 180,000 annually to the municipality, and will benefit a population of over six thousand.

“A city, far from being a cluster of buildings, is actually a sequence of spaces enclosed and defined by buildings.”

I. M. Pei

Public Spaces

Public spaces introduction

Tom Armour,
Global Landscape Architecture Leader

Well-functioning, attractive and comfortable public spaces are vital to the success of any city. For arid cities climate is of course the additional key consideration that links directly to the quality of life, resilience and the economic health of a city.

This section proposes strategies, design approaches and behavioural changes relevant to the planning of healthier public spaces in arid city environments. It considers how we can redesign public spaces to better use precious resources through multifunctional design and recycling. The various components of cities - districts and neighbourhoods to individual parks, streets, houses and open spaces are often the responsibility and remit of a multitude of stakeholders, such as government departments, businesses and civic or residents' organisations, it is important to identify individual actions that can be taken and also where working in partnership would deliver mutual benefits.

A rethink of neighbourhoods and districts in arid environments might, for instance, involve a redesign of systems to enable the conservation of precious resources through multifunctional use and recycling. This could mean a move away from traditional solutions towards the application of new technologies, or the rediscovery of old technologies that have long stood the test of time.

Physical activity is fundamental to human health, but can be a particular challenge in arid environments. In response, public and localised open spaces can provide new opportunities for people to interact outside buildings and cars. And these interventions can be designed to encourage short walking routes between key areas of the city to promote physical activity and help people develop healthier behaviours.

In thinking about healthier lifestyles, it is vital to debunk the popular myth that it is simply '*too hot to walk*' and reduce people's overwhelming reliance on the car.

▲ The Walk JBR, Dubai, UAE

This needs to be supported by investment in the planning and design of convenient walking networks, and resources for effective urban greenery, shading and effective microclimatic design.

The ongoing threat of the effects of climate change makes it necessary to consider designs that both modify local microclimatic conditions, but also underpin plans for longer term resilience and future proofing of urban environments. As cities compete harder than ever to attract investment, successful public spaces, such as squares, streets and parks, have proved to be vital business and marketing tools, essentials to pull in new residents, businesses and visitors.

Rethinking approaches to the design and planning of city components in arid environments reveals that there is a wide range of opportunities to shape better cities. Drawing on research and employing methods from successful case studies will enable individual stakeholders to understand how their actions will lead to greater economic, social and environmental benefits for cities in arid environments.

CASE STUDY 09

Irfan development, Muscat, Oman

A fundamental objective of the Irfan development in Muscat is to create public open space that supports a sustainable community that meets the target of 50% reduction in energy use. The design is sympathetic to the existing topography and landform increasing land value, minimising excavation and retaining natural water flows.

Landscapes use local planting and include on-site food production and the microclimate analysis and passive design strategies underpin street widths and orientations that maximise the passive cooling effect of wind and shade.

Promoting walkability in arid cities

"Walkability is a word that did not exist 20 years ago. We made walking so unnatural that we had to invent a word to describe what we were missing."

Dan Burden, Director of Innovation and Inspiration at healthy living organisation, Blue Zones

The exponential growth of modern cities in arid environments has, for the most part, been underpinned by technological innovations designed to enable comfortable lifestyles in conventionally inhospitable areas. Chief among these is the use of the private car that permits the coverage of large distances in a cool air-conditioned environment.

The car has shaped city making for the last century, and given rise to a number of associated standards and professions whose impact has been to reinforce the car as the dominant feature in the urban fabric. There are currently no 'walking engineers' and only in recent years has a movement emerged to ensure that walking is an integral part of the built environment design process.

As the most basic and essential mode of mobility, walking must be made easy, safe and convenient in cities if they are to achieve the associated environmental, social and economic benefits.[32] Many cities across the globe have implemented changes to urban lifestyles and household patterns that have triggered a new focus on 'walkability'

The inhospitable climate, at certain times of the year in arid cities, has been used by some to suggest that it is 'too hot to walk'. Whilst this may be the case at times of the year, for many months walking is entirely feasible in many arid cities, and can be made more comfortable through good planning and design. It is perhaps the negative attitudes to walking that have caused a lack of coordinated investment in facilities for pedestrians, which in turn has greatly limited any potential for walking.

▲ City Walk, Dubai, UAE

Considerate planning and design is fundamental to create a virtuous circle, whereby walking becomes the most convenient mode of transport in arid cities, particularly in city centres at least for the majority of the year.

Running counter to this, though there is also encouraging evidence of an increasing demand for places to walk in arid environments. For example, the developer Meraas has created a number of walkable schemes in Dubai that, just five years ago, may have been enclosed shopping malls. City Walk, a highly successful retail-led, mixed-use scheme, is designed as a walkable urban environment. Footfall appears high, even in the hottest months of the years, but varies depending on the specific time of day. In addition, quieter periods of the year turned out to have more correlation with school holiday periods, when many families leave the city, than elevated outdoor temperatures.

The heat myth is also being dismantled at the Downtown Project in Las Vegas, where internet entrepreneur Tony Hsieh invested US$350 million to create a vibrant and walkable urban area in the car-dominated city. Hsieh sees walking as a key ingredient in helping create vibrancy through chance encounters and interactions. This, in turn, can help generate innovation and therefore economic benefits to Las Vegas, an emerging tech hub. The associated environmental and social benefits are seen as a welcome side effect of one of the healthiest modes of transport.[33]

Lessons from Downtown Las Vegas

John Curran, Real Estate Portfolio Manager for Downtown Project Las Vegas

The City of Las Vegas was founded in 1905 and most of its explosive growth coincided with the age of the automobile. The Las Vegas valley is filled with 8-lane streets designed for vehicular traffic with air conditioned public transit. Walking and cycling were considered a thing of the past. The Downtown Project, founded in 2012 by Zappos.com CEO Tony Hsieh, has been working to convince Las Vegans to reconsider walking.

I write this on a day with temperatures expected to reach 47.2 degrees Celsius. Admittedly, pedestrian traffic is on the low side today in the twentieth century's fastest growing US city.

But an anecdotal look at pedestrian traffic over the past five years show dramatically increased levels of walking, albeit not fitting with the zeitgeist of most local city planners and developers. Since its inception, The Downtown Project has aimed to redevelop Las Vegas' old centre, promote the benefits of a more walkable neighbourhood and work toward change. Pedestrians in Las Vegas need compelling arguments for why they should ditch the car to which they feel entitled. That starts by making a walk more interesting.

Downtown Project has made substantial investments in street art and installations throughout its real estate holdings. These murals and installations have given character and charm to the Downtown, and as word spreads more and more people come to visit or live in the neighbourhood.

It is difficult to determine an immediate return on these investments, but they make walking more interesting in Downtown Las Vegas and give pedestrians something to look at and discuss on their walk. The investments are specifically tailored to pedestrians and are designed to be enjoyed at walking rather than driving speed to fully appreciate the detail and artistry in the murals and installations.

▲ Downtown Project in Las Vegas, USA

Downtown Las Vegas offers residents and visitors the only neighbourhood with a mix of ground floor retail allowing anyone to easily walk from one bar, restaurant or shop to another. Launched in 2013, the Downtown Container Park was built out of 41 repurposed shipping containers and locally manufactured cubes with small businesses and food and beverage outlets along with a kid's play area and stage. Other improvements include, trees and shade structures, and mist fans installed to help visitors cope with the sometimes-powerful sun and high temperatures.

Lastly, Downtown Project has renovated and built over 700 residential units with nearly 250 more on the way, and boosting residential density in the neighbourhood promotes walkability as well. More foot traffic on the street ultimately promotes economic development and improves the perception of safety on the streets. Downtown Las Vegas has a 'walk score' of over 90 compared to the Las Vegas average of just 41.

It is not always easy fighting the mind-sets of generations of entitled drivers, but visitors and residents of Downtown Las Vegas are learning that walking is possible in a hot and dry city.

Sustainable urban drainage

A common misconception is that storm water management is simpler in arid regions, compared to other parts of the world. However, many cities in arid regions experience periods of high intensity rainfall that can have devastating effects.[34]

The loss of life due to the devastating Jeddah floods of 2009 (122 people were reported dead and over 350 missing), provides a sobering example of the scale of the challenge at hand in arid regions.[35]

Some rainfall events can deliver large amounts of rain during a short period, in the case of the Jeddah floods, twice the annual average in only four hours, this combined with the variability of storms can strain municipal drainage systems. Urbanisation and the use of impermeable surface materials like asphalt and paving stone limit the natural infiltration of water into the ground and increase the presence of toxic chemicals in runoff.

Sustainable Urban Drainage Systems (SUDS) are an alternative approach to managing rainfall that mimic natural drainage processes to control runoff water and filter pollutants. SUDS come in a variety of forms, but generally rely on gravity together with landscape elements such as soils, gravels and plant life to capture, convey and discharge water back into the ground. Common examples of SUDS include bioswales, rain gardens, detention and retention basins.

SUDS act like a 'sponge' during high-intensity rainfall events with strategic design providing places for water to be slowed down or to safely temporarily flood, to help reduce pressure on existing city drainage systems. Opportunities should be sought to integrate sustainable drainage systems within the planning and design of new public amenity areas and retrofit existing flood management infrastructure using more sustainable techniques.

Sustainable urban drainage systems can deliver a number of benefits in addition to controlling runoff and managing flood risks. These include increasing biodiverse habitat for insects and wildlife in the city, providing a natural amenity for people to enjoy, preserving the quality of groundwater, helping reduce urban heat island effects, and improving local air quality.

▲ Newport Beach Civic Center and Park, California, USA

There are good examples for arid cities to learn from around the world. Newport Beach Civic Centre and Park, in California, implemented a series of swales and rain gardens designed to capture and direct surface water runoff and promote infiltration to minimise downstream impacts. The use of native vegetation, bioswales and infiltration basins remove and filter out pollutants from runoff before it enters drains downstream. The selection of appropriate vegetation, able to survive in arid conditions, was a key consideration.

56.1mm

the average annual rainfall in Jeddah

70mm

of rain fell in Jeddah in just four hours in 2009

CASE STUDY 10

The cost of being unprepared, Jeddah Flood, 2009

Climate change is costing the world more than $1.2 trillion annually according to the 2015 Climate Change Vulnerability Monitor. Cities in arid environments are equally vulnerable and will need to adapt to a multitude of challenges such as increasing temperatures and less predictable weather patterns.

In Jeddah, like other arid cities flash floods are a regular occurrence. With the rapid speed of urban growth, unchecked development often takes place in flood prone areas. Cities must address current issues and equally prepare for future more severe stress events.

Community value of public space

"Public space is our open-air living room, our outdoor leisure centre."

Sir Peter Lipton, Chairman, CABE

Public space is a vital aspect of everyday urban life, providing places to gather, shop, socialise, encounter nature and wildlife, exercise and play sport. It also provides somewhere to relax and escape from hectic city routines.

A high quality public environment is an essential investment for any city and has a significant impact on social and economic success, regardless of the climate. Good squares, streets and parks are a vital business and marketing tool as cities increasingly compete to attract investment, new residents, businesses and visitors.

However, in arid regions the number of public places in many cities has shrunk dramatically over recent decades, despite the fact that populations have soared. According to The Economist, the amount of land devoted, per person, to parks, squares and other public spaces in Riyadh, one the most populous cities in arid environments, has fallen by 80% in half a century. Public spaces in Middle Eastern cities currently comprise just 2% of land, compared with an average 12% in European cities.[36]

These detrimental effects have resulted from the increasing transfer of space, from the public to private, in response to soaring development. The key to reversing this troubling trend may lie in promoting a wider and better understanding of the true value of public space and its role in the social, economic and environmental success of many cities. The issue is even more pressing for cities that are dependent on single source revenues and which need to diversify their economies.

In arid cities effective city-scale planning of public space, which is essential to create well-managed and linked resources is even more important than in cities where natural green space is available in abundance. A long term public space strategy, or roadmap, can enable city authorities to focus their resources and plan resilience measures. It should enable work to be carried out in a more incremental way that better responds to available resources and funding.

▲ The Parasol Metropol in the old town of Seville, Spain, provides shade for an inclusive public space, and has become a landmark and point of civic pride

Public health concerns make it essential to encourage physical activity within cities. Well-organised and linked public spaces can help encourage walking and cycling to the benefit of city dwellers. Convenience is key to encouraging people to experience life outside their buildings and cars, to socially interact and connect with nature in support of healthier lifestyles.

The design of public spaces in arid environments should focus on comfort and protection from the elements, and many vernacular and contemporary design approaches can help achieve this. Urban greening in arid cities is an essential need, as it provides shade and contact with nature. With water being a scarce resource, it should be concentrated within public spaces, where it will benefit most people.

Public spaces, by definition, should be open to all people, regardless of race, age or gender and as such they should function as forums for the betterment of citizens and society. When proper investment is made in their design and maintenance, they can bring communities together and encourage social interaction, positive qualities that are at threat in many urban areas.

2%

of land is currently dedicated to public spaces in Middle Eastern cities compared with 12% in European cities.

80%

reduction in parks, squares and other public space in Riyadh over the past 50 years.

Towards a vibrant public realm and open-endedness

Yasser Elsheshtawy, Visiting Scholar in The Arab Gulf States Institute in Washington and Adjunct Professor of Architecture, Columbia University

One of the most profound and satisfying experiences while exploring a city is to discover hidden sites and places. These however are not hidden to the residents and play a fundamental role in a city's social coherence and resilience.

In many of the cities of the Arabian Peninsula inclusive sites and places are rare, could be an empty plot used as a gathering area, an informal community market, or a garden nurtured by residents.

Such discoveries are imbued with a sense of magic. They suggest possibilities within what may otherwise be a bland urban landscape, demonstrating the resilience of the human spirit. At another level such sites also add an element of disorder, thus contrasting with what the anthropologist Marc Augé described as the 'non-places' of the modern metropolis. Their presence provides a counterpoint necessary for overcoming the blandness, monotony and predictability found in many modern cities.

While conventional urban planning has regarded such sites with suspicion, many urbanists, architects, activists and academics, such as Jane Jacobs and Richard Sennett, have pointed out their potentiality since they more than any other space in the modern city evoke a true urbanity predicated on diversity, accessibility and openness. Within the context of the Arabian Peninsula and the gleaming cities of the Gulf, however, the mere existence of such sites can be questioned.

Characterised by high degrees of control and a prevailing sense of order that removes any semblance of informality from its urban spaces such notions are hard to visualise. Yet uncovering and discovering such sites suggests a new way of looking at these spectacular centres thus enabling a more nuanced understanding of its public spaces and their role in society.

▲ Abu Dhabi's 'magical' square with a tree

I have spent more than a decade mapping the existence of such marginal and hidden places. Contrary to common belief in the spectacular cities of the UAE such spaces do exist. And they are not a blight on the urban landscape but are a unique element that contributes to the diversity of public settings that are present in these cities, strengthening a sense of belonging.

In Abu Dhabi a 'magical' square with a tree located in the city's central district, is hidden inside one of its superblocks. The space provides a refuge and is a gathering area for the working class community. Similarly in Dubai the district of Hor Al Anz, offers a vibrant counterpoint to the city's sanitised and highly controlled public settings. Filled with South Asian workers it is an extended living room offering a sense of comfort.

Both these examples provide space where all elements of society can meet, interact and coalesce in a free and uncontrolled environment. A simple street that was meant as a mere conduit for circulation is transformed through the activities of residents in the area into an inclusive public space. Street corners alongside restaurants are teeming with activities that occur throughout the day.

During prayers the overflow of worshippers is absorbed in the city's streets, in entryways to buildings residents chat on their phones with family members in distant lands or to their neighbours, strengthening social bonds. Informal spaces provide us with a sense of magic and the possibilities that exist when places are designed to be flexible and adaptable, making our cities more resilient.

CASE STUDY 11

Lake Mead, Las Vegas, Nevada, USA

Formed by the Hoover Dam, Lake Mead in Nevada, is the largest reservoir in the United States.

The lake, which is fed by the Colorado river, has facilitate the rapid urbanisation of this otherwise arid part of the world. Las Vegas in particular owes its spectacular growth to the water captured and electricity that is generated by the Hoover Dam. Las Vegas and other cities in the American southwest have been designed and evolved ignoring the natural scarcity of water. As a consequence, Lake Mead has not reached full capacity since 1983, due to a combination of drought and increased water demand and as populations grow. The high-water mark, commonly referred to as the “bathtub ring” is now permanently visible, and a constant reminder of the unsustainable levels of water consumption.

Xeriscape

"Public spaces (has) become a vital business and marketing tool: […] In town centres, a pleasant and well-maintained environment increases the number of people visiting retail areas, otherwise known as ' footfall'."

Helen Woolley and Sian Rose, CABE

Manicured lawns came into fashion in 17th century Europe as a status symbol for landowning nobility. The availability of year-round rainfall in temperate climates and on-demand city-wide water systems needed to keep grass in good condition has helped maintain their popularity in modern times.

In modern times, lawns and grass areas have also become popular in arid cities, especially in the Arabian Gulf, and can be seen in city parks and gardens, alongside highways, and at junctions and roundabouts. Roadside grass was originally used to provide instant areas for taking respite from driving when the car first emerged, but has since largely become an expected status symbol.

However, the perennial short supply of water in arid regions should spell the end of the mass application of conventional lawns. Lawns consume huge quantities of water, often taken from unsustainable sources. For example, grass in the Arabian Gulf region is irrigated using desalinated water produced in an energy-intensive process. In the American south-west, large volumes of water are extracted from Lake Mead for use on private and residential suburban lawns which is unsustainable.[37]

In addition, lawns require expensive fertilisers and pesticides, frequent maintenance and can cause issues with groundwater tables and their salinity, in turn affecting building foundations.

Prolonged periods of drought in arid environments have driven interest in water conservation, usurping the idea of lawns as the default ground treatment. Ideally, grass cover should be minimised, restricted only to certain locations where people will benefit, to ensure a more sustainable future.

Many arid regions have adopted the practice of xeriscape, a landscape design approach that requires little or no irrigation, fertiliser and pesticides. Xeriscape is characterised by the use of plant material and practices that require less water, fertiliser and pesticides, the use of native and locally-adapted plants and minimal grass cover.[38]

Xeriscape also provides a pertinent example of how a trend from one arid region can take hold in another, in this case from the North-American Southwest to the Arabian Gulf. This approach also makes the most of the use native plant species and localised plant species, which reduces maintenance. and an active continent spanning horticultural exchange has developed as part of this practice.

In arid cities authorities and designers should take a bold approach and consider retrofitting grass areas along highways and road junctions using 'xeriscape' design to vastly reduce overall water use. They should also enable more effective planting to create shade and shelter.

The use of native and localised plant species and appropriate materials, such as natural gravels, stone and rock, can enhance sustainability as well as celebrate the local landscape character. However, this approach requires a shift in mind-set, to embrace sensible sustainable thinking over concerns with the notion of lawns as a symbol of luxury and status.

A move away from lawns mean developing a new landscape design aesthetic for new and refurbished public spaces and parks in arid cities. Harder ground treatments and a xeriscape approach enable more sustainable use of water to support important landscape functions, such as concentrated areas of large trees for shade, shelter and dust filtering and the creation of better city microclimates.

The development of xeriscape masterplans could become a useful tool to coordinate the long-term development and retrofitting of city spaces. The aim should be to significantly reduce overall water requirements and only locate green areas where they will benefit the largest numbers of people. Such large-scale future proofing could reduce costs, meet environmental, social and practical goals and support the development of healthier arid cities.

CASE STUDY 12

Health benefits of urban nature, Diplomatic Quarter, Riyadh

Research has shown that cities, communities and people need a functioning natural environment as a vital component of a healthy existence.[39] Green infrastructure can support healthy urban populations, climate change resilience, help reduce resource depletion, pollution, and social exclusion - all major global challenges.

The simple, daily connection to nature provides communities with huge physical and mental health benefits, regardless of the region or climatic zone. It is clear that over the last 50 years, with the migration of people to cities, people's connection to nature has in many places substantially deteriorated.

A positive change in urban landscape design approaches in arid environments, can help re-establish vital links to nature and achieve associated social, environmental and economic benefits, without the need to drain precious resources.

To maximise the positive benefits, naturalised areas should be concentrated where people gather or move in numbers within the fabric of cities. Xeriscaping with natural elements such as rock, gravel and stone, in combination with well-considered planting and shading from trees, can create green landscapes that are healthy for the environment and the well-being of people.

Lighting arid cities at night

The needs of an increasingly globalised world have led to the widespread application of the '9 to 5' working day and an increased expectation for 24/7 access to shops, public spaces and other services.

However, this approach is often at odds with the way people live in response to different climates. In arid environments, it has been common to split the day in two, with a break in the middle, to avoid the highest temperatures. And during the hottest times of year, public life has often taken place after dark. Efforts to encourage human activity during cooler times of day and night, supported by innovative technologies, can help create more sustainable arid cities.

The intelligent use of nocturnal lighting could reinforce good city making principles, enhance the cultural experience and encourage social cohesion, by coupling technological innovation with principles and common local practices of activity.

Rapid advances in lighting offer immense opportunities to activate nightlife in urban areas. The most exciting advances are around intelligent responsive lighting, which enables luminaires to be programmed to switch on, or change in brightness or colour, depending on the time and public usage patterns after dark.

At a strategic level, a more considered approach to the planning and design of night-time infrastructure is required. Nocturnal lighting should not be an isolated function, but part of a holistic approach to urban design, focused on creating more vibrant, prosperous, safe and inclusive places.

Lighting considerations should be a core requirement of planning and design policy, rather than a separate initiative. Barriers between different design disciplines, and lighting, must be broken down to ensure a truly human-centric approach and a more cohesive social nightscape. All city making and regeneration efforts must include a night time narrative and engage with relevant stakeholders, including planners, architects, developers, and users of the night-time city to harness the full potential of light and available technologies.[40]

The rapid growth and expansion of cities in arid environments, increasing recognition that they need to be healthier, more sustainable and resilient, coupled with the emergence of new technologies, opens up a range of opportunities to rethink night time design and functionality.

CASE STUDY 13

Yas Island Hotel, Abu Dhabi, UAE

The Yas Island Hotel is the focal point of the Abu Dhabi Grand Prix Circuit and associated development. Whilst built for the primarily to host car races, the track is immensely popular with recreational walkers and cyclists that come out at night, year round.

The Hotel's uniquely lit, ever changing façade adds to the atmosphere and underpins the circuits night time attractiveness and can respond to specific needs.

CASE STUDY 14

Hotel Park, West Bay in Doha, Qatar

Hotel Park, adjacent to the Sheraton Hotel in Doha's Westbay, delivers a new set of design standards and benchmarks for open space development in arid climates. The park, one of the largest decked gardens in the world, establishes a major new piece of public realm in the core of the city, strategically connecting the waterfront, Corniche, convention centre, and financial district.

The park also conceals a four storey deep basement parking garage and retail facilities.

At over 7ha, the park curates a varied and flowing combination of stepped water features, paddle-friendly pools, play areas, restaurant plazas, oasis gardens and picnic lawns for relaxation and exercise.

Lighting design has been a key consideration as usage in the hot summer months shifts after sunset. The park embraces playfulness, creating a new destination in the city that caters for families and is a focal point for social interaction.

“There are fashions in building. Behind the fashions lie economic and technological reasons, and these fashions exclude all but a few genuinely different possibilities in city dwelling construction at any one time.”

Jane Jacobs

Buildings

Buildings introduction

Alisdair McGregor,
Arup Fellow Buildings

Buildings are the private units that connect to the public realm to make cities. They provide shelter from the elements and we spend the majority of our time inside them, irrespective of the climate.

Buildings are responsible for the majority of human resource use and energy consumption and those in arid cities require more resources to achieve human comfort in inhospitable climates. They shape social, economic and environmental aspects of city life; factors that must be considered in any rethink of building design.

If buildings in arid cities are to respond better to their settings, there must be a common understanding that each case is unique and specific. It is not appropriate to merely replicate designs used in temperate environments.

Buildings consume the majority of potable water in any city, which is a particular challenge in arid environments where water is a scarce commodity. The capture, treatment and re-use of water by buildings is therefore essential, and can be enabled by technological innovation and design adaptation.

Buildings have a direct impact on outdoor air temperatures in their immediate vicinity, an effect that is exacerbated in the extreme heat of arid cities. Alternative designs for the building envelope can help mitigate so-called Urban Heat Island (UHI) effects at a city-wide scale.

A better understanding of the impact and path of the sun, façade treatments and materiality, can help buildings passively cool themselves.

Heat exchange, between buildings and the public realm, should be considered, as mechanical cooling systems emit heat during operation and some exhausts push cool air out into the outdoor environment. Specially adapted designs for heating, ventilation and air-conditioning can have a significant positive impact on outdoor conditions experienced by pedestrians, which should be reflected in local building codes.

Buildings in arid environments represent challenges and opportunities. It is encouraging that a number of insights, ideas and innovations now recognise the value they play in making arid cities more sustainable and liveable.

◀ Al Bahar Towers in Abu Dhabi explore how a facade can provide a climate responsive solution in an arid environment

Buildings cooling the city

The extreme heat and sometimes high humidity of arid environments in the summer has resulted in a reliance on mechanical air conditioning to deliver adequate comfort levels and interior temperatures of between 20 and 24 degrees Celsius. As a result, buildings require high performance materials and efficient technologies to control their energy use and limit waste.[41]

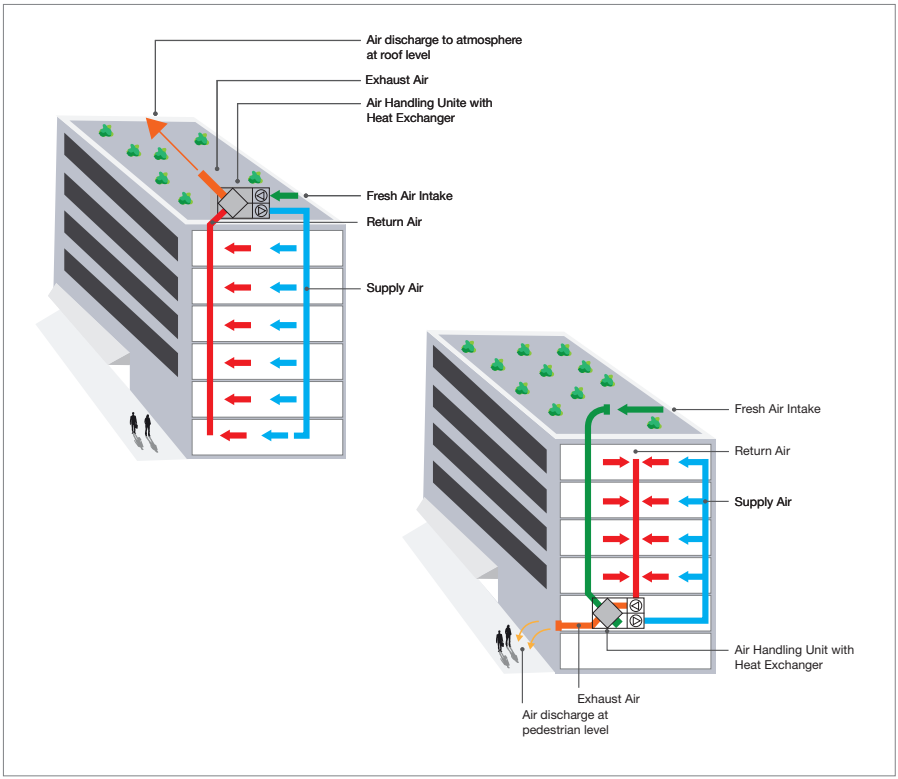
Indoor comfort is important, but it is also vital to consider the impact of internal cooling on the external microclimate. The microclimate of outdoor spaces is defined by air and radiant temperatures, wind conditions and humidity. Buildings are a major contributor to all of these, so more effective building design can contribute significantly to improving external conditions and comfort.

Mechanical cooling systems are typically designed to emit used air through plants located on the tops of buildings. This used air is significantly cooler than the surrounding air, and crucially, still fit for human inhalation. This raises the potential of designing alternative extract systems that push out used cool air at ground level to help cool the city streets.

But buildings can do more than provide passive cooling to improve outdoor comfort, they can become active. Basic good practice, when designing buildings in arid environments, is to aim to reduce the Urban Heat Island effect, which helps reduce reliance on mechanical cooling and air conditioning and therefore cuts energy consumption.

25°C

and more can be the difference between ambient air temperature on hot summer days in Arabian Gulf cities and the cool air that is continuously discharged from buildings.



▲ Conventional cooling systems (top right) and a proposed approach (bottom left) to cool arid cities

Drill down into the details and this approach starts to make logical sense. Mechanically cooled buildings typically draw in a fresh outside air to control indoor air quality, and quality levels are based on established industry guidelines and standards published by CIBSE and ASHRAE.[42]

Holistic building design dictates that supply air delivery should be balanced with a similar level of exhaust air, to avoid over pressurisation. Exhaust air typically comprises a small percentage of poor quality air, containing odours and pollutants, drawn from within building spaces and discharged to the atmosphere. A much larger percentage is typically extracted from generally occupied spaces and returned to mechanical air handling units via a heat recovery system, before being discharged into the atmosphere. The latter is normally low on pollutants and lower in temperature than ambient conditions. This makes it suitable to discharge at pedestrian level in arid cities, enabling the building to actively assist in helping decrease heat islands. This would in turn improve liveability and provide knock on social, economic and environmental benefits at large.

CASE STUDY 15

Terracotta Water Cooling, Noida, India

Ant Studio developed this outdoor cooling device for a factory in India that reduces ambient temperature from 50 to 36 degrees Celsius. The team set out to develop a low maintenance, sustainable and inexpensive alternative to cool the exhaust air, using porus terracotta as a heat exchange medium by using the cooling properties of water, reclaimed from factory processes.

The inspiration for this evaporative cooling installation came from traditional technique and knowledge that traces back to ancient Egypt. The low-tech know-how and local material was optimised by advanced computational analysis and modern calibration techniques. The thickness and the length of the cones were modified with computational fluid Dynamics analysis.

Beyond the functionality of the technical cooling solution, the ultimate design was treated as an art installation. This scalable, simple and innovative low-tech solution achieves the desired environmental outcome whilst also contributing to the general ambiance of a space.[42]

Vertical gardens and green walls

"Green façades are no longer just "architectural decoration", but an essential opportunity to increase the green in our future cities."

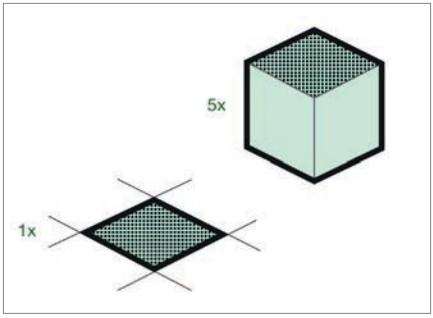
Rudi Scheuermann,
Arup Fellow and Global Façades leader

Green façades have been proven to significantly cool and clean local environments in most climatic contexts, but their suitability in arid climates is a more complex question, influenced by different factors.

The first approach should be architectural, considering factors such as the height-to-width ratio of buildings and streets, and the orientation of street canyons in relation to the path of the sun to help create self-shading buildings and prevent heat absorption. Once these factors have been considered, horizontal, soil-bound green infrastructure can be considered as an additional approach to urban cooling.

Green building envelopes can massively expand the area that support cooler urban environments by providing additional shading and the cooling effect of water evaporation. However, this requires intensive greening, achieved through additional water irrigation, and water is a scarce commodity in arid cities.

The focus should therefore be on implementing plant varieties that are hardy and require little or no additional water. Local plant species should be carefully selected care should be taken to prevent over-exposing the building's thermal mass to the sun. When selecting the most appropriate design solution, it is important to remember that the cooling effects of horizontal ground-bound plantings and plantings in vertical façade systems, are essentially the same.



▲ Greening the façades of a building provides five times the opportunity to introduce nature on the same area

The leaf-area-index (LAI) is a tool that city makers can use to measure a plants' ability to improve air quality. The higher the leaf surface area, the more fine dust can potentially be drawn from the atmosphere. The degree of impact is highly dependent on the general orientation of streets, wind velocity and the distance from pollution sources. Computer fluid dynamic models have shown that green building envelopes typically reduce concentrations of particulate matter by between 10% and 20%.[44]

In addition, green surfaces can significantly reduce noise pollution, depending on the specific coverage area, ambient noise levels, and the distance from noise sources.[45]

The potential for green building envelopes in arid cities to improve quality of life by increasing access to nature and improving air quality cannot be underestimated. Exposure to nature has been proven to enhance people's sense of well-being.[46]

▶ Green wall installation in Dubai

Green, blue and xeriscape roofs

Green roofs in arid cities should be considered as functional spaces, not just ‘green space’, with potential benefits to quality of life and climate change resilience. Their combined impact could be significant when multiplied across an entire city.

Pressure on urban centres in arid environments due to population growth, compounded by depleted water supplies as a result of climate change, elevates the importance of green roofs as a source of energy and water management whilst also providing outdoor spaces for humans to use.

Arid environments are prone to low rainfall, but often experience sudden violent storms that can quickly overwhelm city drainage systems and cause blockages due to the amount of fine sand. These sudden events are becoming more frequent as a result of climate change.

So-called ‘blue roofs’, developed in the Netherlands, could be installed to capture, filter and temporarily store storm water, then slowly release it back into drainage systems. A single blue roof may retain a relatively small amount of water, but multiplied across a whole city the system could have significant impact helping build resilience.[48]

Utilising roof space for people or biodiversity can ease pressure on development land and increase the attractiveness and saleability of properties by providing outside space for residents, workers and visitors.

50°c

higher temperature on a conventional roof in the height of summer compared to a vegetated roof that is close to the ambient temperature.[47]

▲ Brewbooks Cactus Garden Roof, Getty Center, Los Angeles

Such spaces need not be 'green' in the traditional sense, water intensive, or high maintenance. A xeriscape approach, using plant species selected to maximise effective shade and shelter and reduce noise, glare, dust and air pollution, can deliver visually attractive and highly functional areas, with a microclimate suitable for people to enjoy throughout much of the year.

Green roof designs in arid climates should aim for a larger percentage of hard surfaces and fewer green elements, placed for maximum visual and functional effect, reducing the need for irrigation water. The use of gravel, rock and stone requires little upkeep and can deliver many of the same benefits as a planted garden roof.

Research has shown that a roof with high-albedo hard materials (materials that reflect sunlight) such as gravel, can create an effective insulation layer to help thermally cool buildings, improve the performance of mechanical systems by reducing the ambient temperature where fresh air intakes are positioned, and help cool solar panels to increase their effectiveness.[49]

Roof gardens, whether xeriscaped with drought resistant plants or hard surface materials, make sense in arid environments where population growth and climate change put pressure on resources. Increasing the functional potential of roofs can add stormwater resilience, create more usable space for people, including microclimate and pollution control, and boost insulation and energy production.

CASE STUDY 16

Bosco Verticale, Milan, Italy

This vertical forest in the heart of one of the Europe's most polluted cities brings 900 trees along with 5,000 shrubs and 11,000 floral plants to these two towers. The vertical green-space does not only address pollution, noise and vibration issues, but also provides a biological habitat of 40,000m^2 in a densely built up urban environment. The designers aim to inspire greater urban biodiversity in the face of Milan's challenge of increasing pollution.

The Bosco Verticale provides an inspiring exploration of what high-rise living in an Arid Environment could look like providing much needed green space vertically rather than horizontally. Green façades and roofs have the doubling effect of contributing positively to the urban environment and citizens mental and physical health, whilst also reducing operation cost due to reduced cooling requirements.

From initial trials, vertical Green Spaces in cities such as Dubai, are more resource efficient in terms of its water use than horizontal green space, if the microclimate is correctly considered or created. Irrigation can be also easily extracted from buildings themselves by using greywater recycling with progressing innovation and improved designs, maintenance are becoming more efficient.

Recycling water from buildings

"If anything, recycled wastewater is relatively sweet to taste."

Professor Anas Ghadouani, Regional Executive Director
Water Sensitive Cities, University of Western Australia

Almost every building used by humans requires a constant supply of potable water, which is a major challenge in arid environments where water is a scarce resource. The problem of a secure water supply is only likely to intensify in response to population growth and climate change.

The consumer price of water in arid environments does not often reflect the full cost of production and distribution, underlining the need to improve water conservation and implement measures to preserve or recycle this precious commodity.

Several design strategies can be employed to help reduce water consumption in buildings and decrease the demand for fresh water on municipal sources. Plumbing systems can use low and ultra-low flow water fixtures and aerators. Exterior landscaping, including green roofs and walls, can be irrigated using drip or subsoil water delivery systems.

Recycled water has even greater potential to reduce demand. Every building generates wastewater which is then channelled into city level drainage networks. This water is then pumped to a treatment facility, which requires significant infrastructure, high capital costs and substantial amounts of energy to operate. Bringing that recycled water back into the city requires additional energy, infrastructure and costs.

51%

of people from a recent survey in the US were unsure of, or refused to try, recycled wastewater

62%

of residents in Toowoomba, Queensland voted 'no' to a water recycling referendum

Decentralising the recycling of water to a building level, similar to the current move towards decentralised energy generation, could lead to significant cost savings.

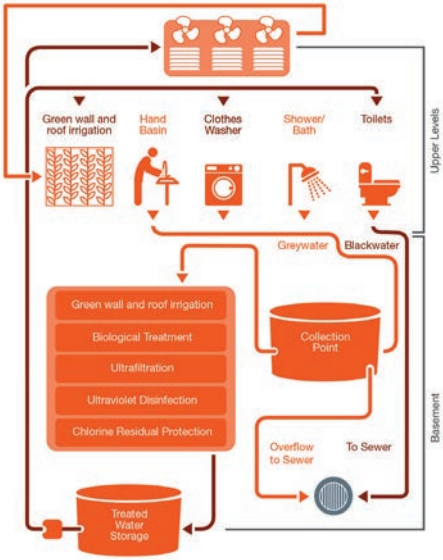
Although on-site water treatment requires careful planning and investment in new building systems, it is feasible to design entirely closed water recycling systems within buildings at scale.

As much as 50% of a building's water discharge is considered greywater and can be effectively treated to be brought back into positive use. Greywater is derived from sources such as showering, washing, and condensation from air handling units and cooling towers.

For example, the amount of condensation generated from air handling systems is generally higher in arid environments that are subject to periods of high humidity. This is water which could be put to a number of uses in buildings.[50] The minimal treatment needed to clean greywater could be combined with green roof systems that use natural filtration processes.

In recent years, other innovative treatment systems that use micro-organisms have been developed to treat blackwater from human waste into productive uses. In general terms, recycled water needs to be the focus of more research and creative thinking to help optimise its use in buildings in arid environments.

▼ The building water recycling opportunity



Don’t we already all drink recycled water?

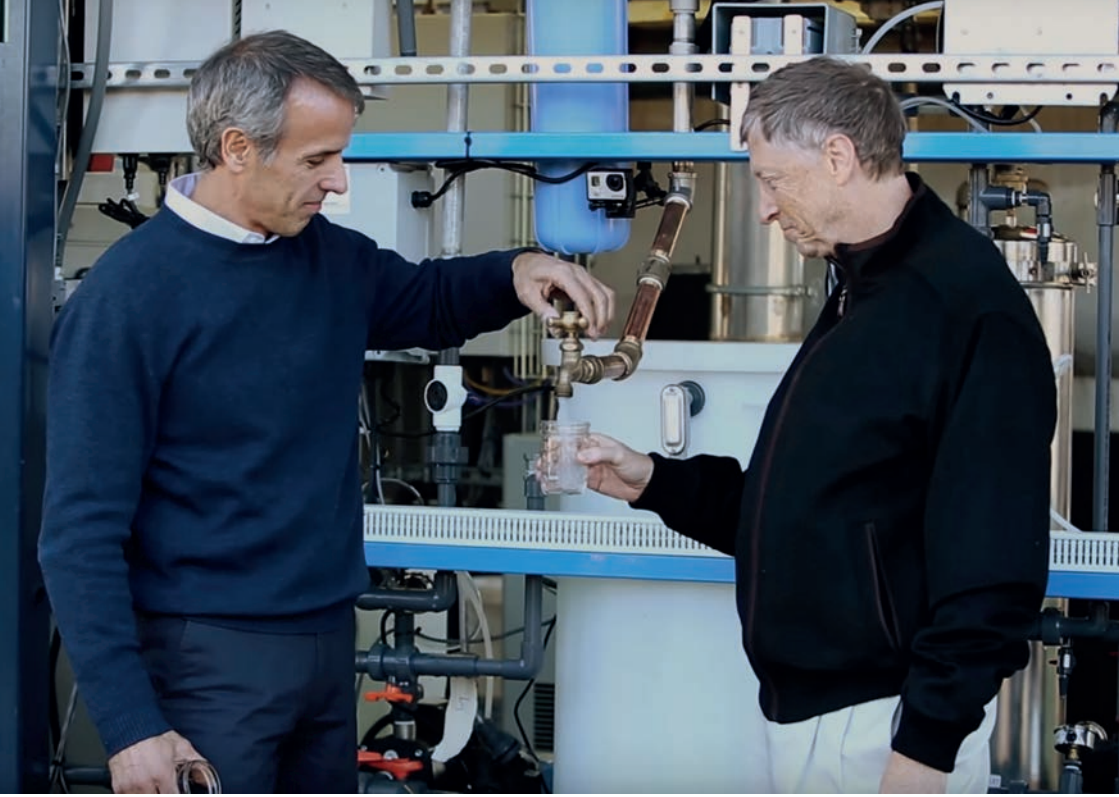
Water reuse and recycling should be an everyday practice for cities in arid environments, yet it seems not to have gained widespread acceptance, and is often stigmatised. Change will require a different approach to planning and designing choices, supported by positive messages to transform this cultural taboo into a mainstream practice.

Water recycling is vital as the effects of climate change and rapid urbanisation threaten the availability of natural water resources. However, public concerns about the perceived health risks of using recycled water have hampered its widespread application, even for non-drinking purposes such as watering gardens or flushing toilets.

A social stigma towards drinking processed and recycled wastewater has developed in many arid cities, which has prevented more widespread acceptance. A recent survey in the US, found that 51% of people were unsure of, or refused to try, recycled wastewater.[51] In Australia, 62% of residents in Toowoomba, Queensland, a city plagued by dwindling water resources and expensive desalination costs, voted ‘no’ to a water recycling referendum.[52]

In addition, a survey of residents in Jordan revealed that almost 30% disagreed with or were unsure about grey water use for irrigation purposes.[53]

Widespread adoption of water recycling requires public assurance, acceptance and enthusiasm. This may be as simple as a subtle shift in nomenclature and branding that could help catalyse a change in mindset. Engineering terms like ‘greywater,’ ‘toilet to tap,’ and ‘recycled wastewater’, are not helpful and could be replaced by more uplifting terms such as ‘showers to flowers,’ ‘laundry to landscape,’ or ‘purified’ water, to help reframe the debate.



▲ Public showings of influences and politicians help break down stigamas around recycled water

In the words of Eric Garcetti, Mayor of Los Angeles: “Showers to flowers lets people know that the water is and always was part of a natural cycle. When you can help people realise that all of the water we have, we’ve always had, and that even water molecules in the freshest mountain spring water may have passed through a toilet at one point, their perspective starts to shift.”

Great results are achievable. For example, a behavioural change programme and other water recycling incentives in Los Angeles resulted in a 19% reduction in residents’ water usage, between 2014 and 2017.[54] Similar efforts, in arid environments, will be needed to dispel misconceptions and secure the water supply for future generations.

Fog and dew harvesting

Fog harvesting, in order to obtain fresh water, is an ancient technique not isolated to arid environments. In the high altitude mountains of the Atacama Desert and in Morocco, efforts are underway to improve efficiencies of old techniques by applying modern technology.

The concept of harvesting water from the atmosphere in the form of fog and humidity for human consumption and irrigation is a tried and tested practice in many parts of the world. However, recent research has demonstrated how harvesting systems and materials can be optimised to extract large amounts of water, even in arid environments relatively low levels of humidity.

Fog-water harvesting systems have been used in Chile since the early 1900s. Pilot projects implemented from the 1980s onwards used fog capture nets to grab water from thick fogs in the remote Atacama Desert.

More recently, Chilean scientists have demonstrated the potential to increase yields from fog nets five-fold, by optimising the design and materials and using modern computers.[55] The concept was co-opted by local architects to produce concept designs for a spiral 'fog-harvesting tower' able to capture water from coastal fogs for irrigation in the arid agricultural region of Huasco, Chile.[56]

▲ A fog catching net in the Atacama desert

Fog-harvesting has also been explored in Ifni, in Morocco where it has brought social and economic benefits to rural communities who depend on water for livestock farming and who are pressured into urban migration due to water scarcity.[57] It has also been demonstrated in parts of the Middle East, such as Asir, Saudi Arabia[58] and the south coast of Iran.[59]

▲ Fog is a common occurrence in Dubai and other arid Gulf cities

Studies there have shown that fog harvesting is highly dependent on regional topography and wind direction. Even inland sites however can generate up to seven litres per square metre.

Other projects have explored the potential of capturing dew to bolster water supply. Residents living in the hot and arid region of Kutch, in Gujrat, India must normally truck in water long distance due to the lack of local natural sources. A number of pilot projects have been deployed to capture dew water by condensing it on thin plastic film installed on large roof and open ground surfaces.

The system has proven to be both, affordable and easily maintainable.[60]

Scaling up fog and dew-capture approaches could make a fundamental improvement to the provision of water in cities in arid environments. Innovations to existing water-harvesting systems, driven by advancements in material development and technology, could enable the efficient use of façade and roof spaces to extract water in cities.

The Sustainability Pavilion at the upcoming Dubai Expo 2020 will showcase innovations in water harvesting technology, including hybrid structures that generate renewable solar energy and capture water from humidity in the air, to supply a significant proportion of the pavilion's water requirements.[61]

Spearheading the world's quest for sustainability from our desert homeland

Marjan Faraidooni, Expo 2020 Dubai,
Senior Vice-President of Legacy Development and Impact

For millennia, sustainable behaviour has been essential for the survival of people in this region. Today, lessons of using natural solutions are invaluable to us as we develop models to sustain the growing cities in our region, but also how the lessons we have learnt can be shared with other parts of the arid world.

These considerations are central in shaping the design of both the future Expo 2020 Dubai site and its pavilions.

One of the most ambitious structures at Expo 2020 Dubai will be the Sustainability Pavilion, which has been designed and engineered by combining human ingenuity and the genius of nature. As the first World Expo hosted in an arid environment, Expo 2020 will place sustainability and the well-being of future generations at the core of its ambition to foster innovative thinking and behavioural change.

Understanding that we live at a tipping point in human history, Expo 2020 Dubai advocates the power of connecting minds, across sectors, organisations and geographic borders to accelerate and share solutions for more sustainable cities and communities.

The Expo's Sustainability Pavilion is a focal point of the Expo site, and a cornerstone of our ambition to leave a legacy that will inspire visitors to take action both during and long after Expo.

More than a building, the Pavilion is designed to be a 'machine' whose intricate parts are inspired by nature itself; they are designed to meet the underlying engineering challenges of building a largely self-sustaining system, providing much of its own energy and water needs.

In one of the largest-ever applications of such technology, the Sustainability Pavilion employs cutting edge solutions to produce its own energy through 10,000 square metres of solar panels. It also produces its own water by recycling waste water and harvesting it from the humid air.

▲ Proposed Sustainability Pavilion at the World Expo 2020 in Dubai

The ‘energy trees’ that surround the pavilion are also equipped with solar panels that follow the movement of the sun to harvest its power. The landscaping uses native plants which have evolved over millennia to be perfectly adapted to the arid conditions. These plants, like the pavilion and energy trees, reflect and symbolise the stories of human survival, ingenuity and culture of the lands that now comprise the UAE.

Beyond its striking architecture, the Sustainability Pavilion is designed to be an inspiring and fun place simply to visit and learn. It will be a place that will complement all the efforts invested towards sustainability locally and regionally by showcasing innovation and solutions that have the potential to provide insights as to how we tackle climate changes, water shortages, agriculture challenges, food production and sustainable urbanisation.

As we plan the lasting legacy of the Pavilion, we will draw from the greatest renewable resource of all, our youth. The Pavilion will thus be a pivotal space for future generations to be inspired and to contribute to the development of sustainable communities in the UAE and beyond.

Expo 2020 will empower young people with the belief that any positive impact that we create starts within them.

“Make big plans; aim high in hope and work, remembering that a noble, logical diagram once recorded will not die, but long after we are gone be a living thing, asserting itself with ever-growing insistence.”

Daniel Burnham

Way Forward

Time for an arid city paradigm

During this pivotal time in our planet's history we must rethink how we make cities and how we retrofit them for the future. This rethink is even more critical for cities in arid environments as the effects of climate change are likely to affect them more severely.

The rethink should both draw from the past and look to the future, combining the wisdom of centuries of city making in arid environments with best practices and emerging technologies in sustainable urbanism.

The current climate change debate is being framed with increasing urgency as an issue of survival for cities in arid environments, yet decision makers in public and private sectors have been reluctant to commit to embrace adaptive design and mitigation measures in their projects.

While many acknowledge the risks of climate change, and express tacit support, often the duty for action is passed on to others and neglected. In this context, city makers have a critical role to play in helping their stakeholders understand the transition to more sustainable urban practices.

These must be seen as a long-term goal that not only delivers environmental and social advantages, but critical economic benefits as well.

A paradigm shift is needed that repositions the conversation about climate change and sustainable city making away from being seen as a development challenge towards a development opportunity. The technology and know-how to make this shift are available, and the lessons and best-practices from leading arid cities are there to be learned.

The focus going forward should be on expanding and sharing these practices and supporting arid cities in this transition.

A number of tools are available for arid city leaders to help them make this transition:

Cost/benefit analysis

Undertaking a comprehensive and scientifically rigorous cost/benefit analysis is one of the most powerful tools to make the case for climate mitigation and adaptation projects. Such models illustrate the impacts of climate mitigation over time and demonstrate the potential gains from early action, versus the rising cost and the risk to infrastructure assets when action is taken at a later date. Cost/benefit analysis models allow practitioners to model the effects of rising temperatures on resource use, model the economic impact of rising sea levels, to inform smarter design and decision making for the built environment.

Incentives: green funds and banks

Over the past decade a number of collective green funds and banking structures have been turned into multinational agencies to fund climate adaptation strategies and projects, including those for public transport and energy. Cities in arid environments can access these funds by proposing suitable projects that meet developmental needs and respond to relevant funding requirements and standards. This could be an effective tool for persuasion and to package together numerous climate responsive projects.

City-to-City learning and competition

Dialog and knowledge sharing between arid city leaders is critical to supporting the transition towards more sustainable city making. Networks like C40 Cities, Compact of Mayors and 100 Resilient Cities provide a forum for city-to-city learning. These networks also provide a form of accountability as member cities declare their intention to become more sustainable. Friendly competition between member cities can also incentivise action.

CASE STUDY 17
Masdar, Abu Dhabi, United Arab Emirates

The sustainable city of Masdar is an ambitious project in Abu Dhabi that has bee envisioned as a living urban laboratory. The city is set up to explore the post-carbon future of sustainable cities in the hot, hyper arid environment of Abu Dhabi.

The city is anchored around the Masdar Institute, which is carrying out pioneering research into new ways to achieve more sustainable buildings, infrastructure, and ultimately, cities in arid environments. It also provides an incubation environment for urban innovations, in areas as disparate as mobility and power generation, to be tested for future implementation.

Masdar is now also home to some of the region's most sustainable buildings, and the International Renewable Energy Agency (IRENA), has recently built it's sustainable headquarter there.

Whilst Masdar had to adjust its grand ambitions to commercial realities, it nevertheless provides valuable lessons learned to cities in arid environments elsewhere, in low- and high-tech intelligent city making.

Future of arid cities

What will arid cities of the future look like? How will they face the twin challenges of climate change and population growth to build urban environments that are sustainable and resilient? How should arid cities address these challenges and plan for the future? How can they incorporate technological innovation and rediscover historic expertise?

This report has outlined three principles to guide strategic thinking for arid city leaders:

Learn from the past and build on locally adapted climate-specific design solutions

Invest in green and blue infrastructure that is designed to work with local environmental and ecological systems

Design intelligent buildings and public spaces that can meet the needs of people in a changing climate

The application of these principles will look different depending on the specific context. The social, environmental, political and economic context as well as the level of technological advancement and crucially changing climatic context.

While this report explores 15 ideas for sustainable urbanism in arid cities, the large takeaway is that a one-size-fits-all approach is not appropriate. Arid cities require a tailored approach, grounded in the local context and responsive to the specific challenges faced at the scale of the city, public space and individual buildings.

Cities

The challenges associated with sprawl and unsustainable urban development have been especially severe in arid cities and are being exacerbated by climate change and population growth. Arid cities need planning and design strategies that are adapted to the local climate and that work in harmony with local ecosystems. Sustainable ground water management, for example, and initiatives that help cities contain desertification and deal with seasonal flooding are examples of ways that urban infrastructure can work with natural systems to make arid cities more livable.

Public Spaces

When thinking about the development or redesign of cities in arid environments, recognising the fundamental role that public and ‘green’ spaces play for mental and physical well-being is essential. Access to green space, and the water resources to support these spaces, is a critical challenge that arid cities need to address, whilst also becoming less car dependant. The most effective design solutions will be ones that deliver social as well as ecological benefits together, leading to vibrant cities that attract and sustain people in challenging environment.

Buildings

Historically, the architecture of a building was reflective of the local environmental context in which it was found. Buildings in arid cities today, however, are often engineered for climates and contexts that are not arid. In the coming century, there will be a need to retrofit these buildings and design new buildings that are more sensitive to local conditions. New innovations in building technologies are one approach, but much can be learned from more traditional vernacular architectural techniques with interesting opportunities to adapt these for the 21st century.

Model arid city

This model city gives an overview of how the explored strategies, case studies and reflections can help shape the re-design and development of cities in arid environments; making them more sustainable, healthier and better places to live.

On the following pages we provide some thoughts for future actions, grouped into cities, public spaces and buildings.

Cities

1. Preventing urban sprawl
2. Aquifer recharge
3. Attitudes to recycled water
4. Active lifestyles
5. Policy and fiscal incentives
6. Development densities
7. Green investments
8. Decentralised infrastructure
9. Groundwater management
10. Social interaction
11. Improved air quality
12. Civic pride

Public Spaces

13. Designing for walking
14. Future-proofing mobility
15. Efficient irrigation
16. Nocturnal lighting
17. Xeriscaped landscapes
18. Having fun
19. Sustainable drainage
20. Inclusive spaces
21. Permeable pavements
22. Addressing intrusion
23. Productive landscapes
24. Complete streets

Buildings

25. Responsive building façades
26. Biodiversity
27. Localised vernacular
28. Microclimate
29. Dew harvesting
30. Greening buildings
31. Building orientation
32. Green and blue roofs
33. Indoor-outdoor spaces
34. Innovation in cooling
35. Recycling water
36. Low-tech innovation

Possible actions
Cities

1. Preventing urban sprawl

Sprawling cities encourage car-dependency, increase pollution, and foster isolation. Controlling both overly dense high-rise schemes and too low-density developments can enable well-designed, balanced and lively communities with good access to public space and community facilities.

2. Aquifer recharge

Cities generate wastewater, and developed cities often produce surplus desalinated water. When treated, this water can be used to replenish natural geologic water storage formations, and create reserves for arid cities' water resilience in times of stress.

3. Attitudes to recycled water

People must be encouraged to be positive about re-use of recycled water, as this helps ease the strain on limited supplies. Public awareness campaigns can reframe this difficult issue in a more positive light to win people's support.

4. Active lifestyle

Challenging climates should not mean reliance on the private car as the only mode of transport, the main cause of sedentary lifestyles. Through considerate planning and design, the demand for public transport can be increased, walking and cycling can be made safe and pleasant resulting in more active lifestyles.

5. Policy and fiscal incentives

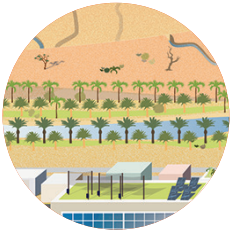
Projects that meet developers needs whilst achieving arid climate-responsive standards need support to become the new norm. Planning policy, green funds and banks can be aligned to incentivise developers towards a proactive rethink of business-as-usual.

6. Development densities

Even where using up new land seems easy, as where there are no natural constraints such as topography or the sea, policies that limit the supply of land are necessary. To achieve a mix of land uses at appropriate densities to help keep cities compact, improves sustainability and social cohesion.

7. Green investments

Investing in afforestation can create greenbelts around urban centres that significantly reduce wind speeds, dust pollution and halt desertification. They also create economic opportunities, and arid cities must ensure investments meet more than one objective.



8. Decentralised infrastructure

Innovation in power generation, water treatment and waste management are creating opportunities to create scalable and more sustainable urban systems. This is particularly beneficial in rapidly growing cities, where infrastructure is often lagging behind urban development.

9. Groundwater management

Arid cities must manage issues with groundwater tables by reducing the number of infiltrations and maintaining water quality. Pumping, metering and other measures help prevent flooding, contaminations or damage to infrastructure and building foundations.

10. Social interaction

Arid cities can become more liveable by providing space where public life can take place outdoors more sustainably. A focus on comfort and protection from the elements allows life take place outside buildings and cars.

11. Improved air quality

The built environment can actively tackle issues regarding particles in the air, whether created by human activity or from dust and sand being blown in. Greening and sheltering cities are key opportunities, also providing economic and well-being benefits.

12. Civic pride

Residents of a city need to invest in where they live: emotionally as well as financially. Major arid cities tend to be relatively new, so fostering a sense of togetherness and belonging, by providing spaces to express civic pride, is a key investment into their future.

Possible actions
Public Spaces

13. Designing for walking

Despite the inhospitable climate providing an easy excuse, (hot) arid cities can be planned and designed to be walkable. Walking is a key ingredient in creating vibrant and inclusive cities, with immense personal and public health benefits.

14. Future-proofing mobility

Future transportation technologies can enable the design of narrower streets and the use of different road surfaces. Increased manoeuvrability and lower heat emissions, as well as reduced need for parking, are key opportunities.

15. Efficient irrigation

Recycled water can be used to irrigate an increased amount of vegetation in arid cities using appropriate species. It must also be designed and monitored to reduce wastage and not harm the groundwater table.

16. Nocturnal lighting

Public life in arid cities often takes place after dark to avoid the hottest hours of the day. Intelligent and responsive lighting that changes with public usage patterns can be used to create a 24-hour city.

17. Xeriscaped landscapes

Adopting the use of natural materials such as rock, and native or locally-adapted plants, create attractive urban spaces. This also provides an economically and ecologically viable response to climatic and resource challenges.

18. Having fun

The arid city must not only shelter its residents and foster their well-being, it must create enjoyable environments for all its residents. Retention ponds, for example, are aimed to tackle seasonal nuisances such as flooding, but they also offer the opportunity to become settings for cherished events.

19. Sustainable drainage

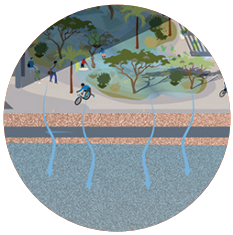
Sustainable urban drainage can help cope with sudden and intense rainfall, preventing flooding and social and economic losses. Swales capture and direct water runoff and allow infiltration, to minimise damage whilst also removing pollutants.

20. Inclusive spaces

A people-first attitude must be the basis of design for inclusive spaces that provide an opportunity for all elements of society to interact. They must be flexible and adaptable, to create a sense of community and safety amongst the residents, and to make the city more resilient.

21. Permeable pavements

Minimising hardscape and incorporating more natural and permeable and porous surfaces will mean that the ground absorbs and stores less heat than with asphalt and concrete. This reduces the Urban Heat Island effect, and will also promote water infiltration during storms.



22. Addressing intrusion

In coastal areas, increased irrigation needs careful management. It can lead to higher water tables, in turn leading to saltwater intrusion. Increased salinity adversely affects natural and planted vegetation, and it can also damage infrastructure and foundations.

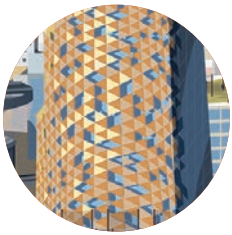
23. Productive landscapes

Investing in vegetation such as forest belts is a substantial commitment of precious resources for cities in arid environments. Landscapes need to play more than one role and must contribute economically, environmentally and socially to the well-being of the city.

24. Complete streets

Complete streets are designed as multimodal public spaces. Adopting a complete streets concept provides a more balanced transport system and optimises road space. This approach to road design contributes to changing travel patterns and behaviours, aiding a more active and sustainable lifestyle.

Possible actions
Buildings



25. Responsive building façades

Consideration of temperature must be the key driver in façade design, minimising heat gain. Innovation in glass that reflects heat from the sun can reduce temperature, as do responsive modular shade structures that follow the sun.

26. Biodiversity

Developing roof spaces is not only for its human users. It also creates room for biodiversity, mitigating the loss of habitats to urban development. This increases the attractiveness of properties, by providing a natural space for residents, visitors, birds, wildlife and plants.

27. Localised vernacular

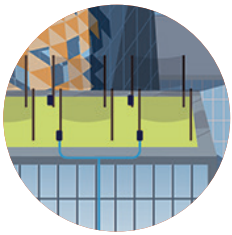
Traditional urban heritage and aesthetics, including flat roofs and thick walls with small windows, reinventing localised vernacular. Combined with modern technology buildings that use fewer resources, generate less waste and help preserve the uniqueness of place-specific vernacular are created.

28. Microclimate

Urban planners and designers must design built environments that remove climatic stresses and minimise thermal discomfort. This also includes reducing dependence on cars and their infrastructure which add to heat, noise and air pollution.

29. Dew harvesting

Harvesting structures and thin plastic films installed on roofs, building façades and open spaces can capture water from the air. Technology is increasing the efficiency of this ancient practice, providing innovative and affordable methods to improve the provision of water in cities.



30. Greening buildings

As cities grow, more pavements and buildings are being created. Retrofitting buildings with green roofs and walls is a way to provide valuable new ecology without the need for more land, in addition to tackling noise, heat and pollution.

31. Building orientation

Digital analysis to simulate wind flow and shading can guide new development and regeneration projects. With technology it is now easy to define appropriate building and grid orientation, in order to maximise natural passive cooling in arid environments.

32. Green and blue roofs

Green and blue roofs can be used for water management and to create resilience in built environments. Green roofs improve the building's mechanical cooling systems performance and insulation, and blue roofs can filter and store storm water.

33. Indoor-outdoor space

In modern arid cities, useable public space is being replaced with indoor spaces, that are mainly private and trap activity year-round. Seasonally adaptable and accessible spaces that are designed to open during more temperate seasons, create a sense belonging and comfort for all residents.

34. Innovation in cooling

Buildings can be designed to play an active role in reducing reliance on air conditioning and mitigating the Urban Heat Island effect. Alternative extracting systems can direct used air from occupied spaces, pushed out at the pedestrian level to help cool the streets.

35. Recycling water

A building's demand for freshwater can be partially met by treating and reusing its own supply of greywater. Use of greywater is also ideal for the irrigation of vegetation on a building's walls and roofs.

36. Low-tech innovation

Air and water movement or whitewashing buildings have been used for millennia to address heat, but have been abandoned in favour of mechanical cooling. Rediscovering ancient techniques and local materials, and pairing them with advanced computational analysis, can provide sustainable alternatives to air conditioning.

CASE STUDY 18

Cool Pavement, Los Angeles, USA

The city of Los Angeles has begun coating its streets with a special paint, CoolSeal, that will reduce the temperature of the city. In an initial test it has been shown to reduce ambient temperatures by 6.6 degrees Celsius and is now being rolled out a larger scale. It is one of the city's initiatives to combat the effects of climate change and will provide lessons learned for other cities dealing with Urban Heat Island effect and other issues.[62]

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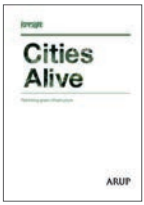
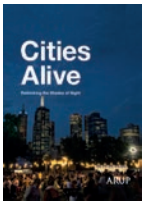


Rethinking green infrastructure

Cities Alive looks at how we can build nature into our urban systems at all scales through high quality landscape design, via new development or retrofitting through a green infrastructure design approach. The publication analyses existing research and trends in landscape design, drawing out key elements which can help deal with rapidly rising urban populations, mitigate climate change and produce integrated solutions.



Rethinking shades of night

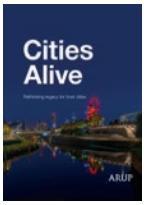
Rethinking the Shades of Night looks at the role of light in creating human-centred urban night-time environments. The report emphasises a more context-sensitive design approach and a holistic integration of lighting infrastructure into the urban fabric. It focuses on the human factor and ways to enhance the experience and use of public space during the hours of darkness.

Towards a walking world

Mobility is intrinsic to the quality of life experienced in cities. But for the past century, the car has dominated how we plan and grow our urban areas. With a growing desire to create more liveable streets, a light needs to be shone upon the benefits of walking as a catalyst for developing sustainable, healthy, prosperous and attractive cities.

Green building envelope

In ever denser cities the space for green infrastructure, such as parks and green recreational spots, is being depleted. What is often considered as “green architectural decoration” is, however, an important element in our built environment and should not be underestimated. The comprehensive research considers whether green building envelopes can have a special role to play in improving our cities for their inhabitants.



Rethinking legacy for host cities

Major sporting and leisure events are under scrutiny like never before to deliver long term benefits for their host city, and the citizens within them. Arup is rethinking legacy. From venue optimisation, through to innovative finance models securing long term investment, we believe there are new ways to help cities achieve long term value and increased civic engagement through hosting.

Designing for urban childhoods

A child-friendly approach to urban planning is a vital part of creating inclusive cities that work better for everyone. Through 40 global case studies, 14 recommended interventions and 15 actions for city leaders, developers and investors and built environment professionals, the report shows how we can create healthier and more inclusive, resilient and competitive cities for us to live, work and grow up in.

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