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Sustainable Water Management

Assessment and Recommendations for the Emirate of Abu Dhabi

Prepared for the Abu Dhabi Urban Planning Council

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PREFACE

The following report consists of work completed by our team of 14 students over the 16-week Spring 2010 semester during the Workshop component of the MPA in Environmental Science and Policy (MPA ESP) program at Columbia University's School of International and Public Affairs. The MPA ESP program trains its students to use and apply innovative systems-based thinking when approaching environmental issues. The program's core curriculum prepares students to analyze and understand the formulation and management of public policy by challenging students to think systemically and act pragmatically. The Workshop in Applied Earth Systems Policy Analysis and Management provides an opportunity for students to apply their theoretical knowledge and functional skills to address real-world environmental policy and management issues.

For our Workshop project this semester, our team has been asked by the Abu Dhabi Urban Planning Council to help develop and recommend appropriate public policy for the sustainable management of water in Abu Dhabi. The primary focus of the research problem presented to the team was to establish policy that will engender long-term sustainable consumption of water sources. To accomplish this, our team explored both the supply and demand sides of water in Abu Dhabi and their related policy issues. The following report represents the set of public policy recommendations that our team has identified for the integrated and sustainable management of one of Abu Dhabi's scarcest resources—water.

ACKNOWLEDGEMENTS

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CONTENTS

By the year 2012, estimates indicate that water demand in Abu Dhabi will exceed water supply. This report is intended to support efforts by the Urban Planning Council (UPC) and other agencies of Abu Dhabi to suggest policy, take immediate action, and develop both immediate and longer term strategies to achieve sustainable water management. We recommend that the Urban Planning Council (UPC) pursue a sustainable water management campaign, which, if properly executed, can ensure the continued quality of life and economic prosperity of the Abu Dhabi city and the Emirate.

We address both water supply and demand issues; however, most of our recommendations focus on the demand side. The reason for this is straightforward: water is over-consumed in Abu Dhabi given current supply. There are many reasons for this high water consumption; however, we have identified four principal drivers for the current over-consumption of water within Abu Dhabi:

1. A non-integrated approach to water resources management across agencies and governing bodies in Abu Dhabi; coupled with,

2. Inconsistent and unreliable data to properly quantify and understand the issue of water resources, consumption and waste; leading to,

3. A general absence of awareness about the need for and desirability to reduce consumption as an essential component in water sustainability; linked to,

4. The absence of a price for water in Abu Dhabi. While water may have a high normative value among the populace, consumption needs to be informed by both economic and environmental valuation.

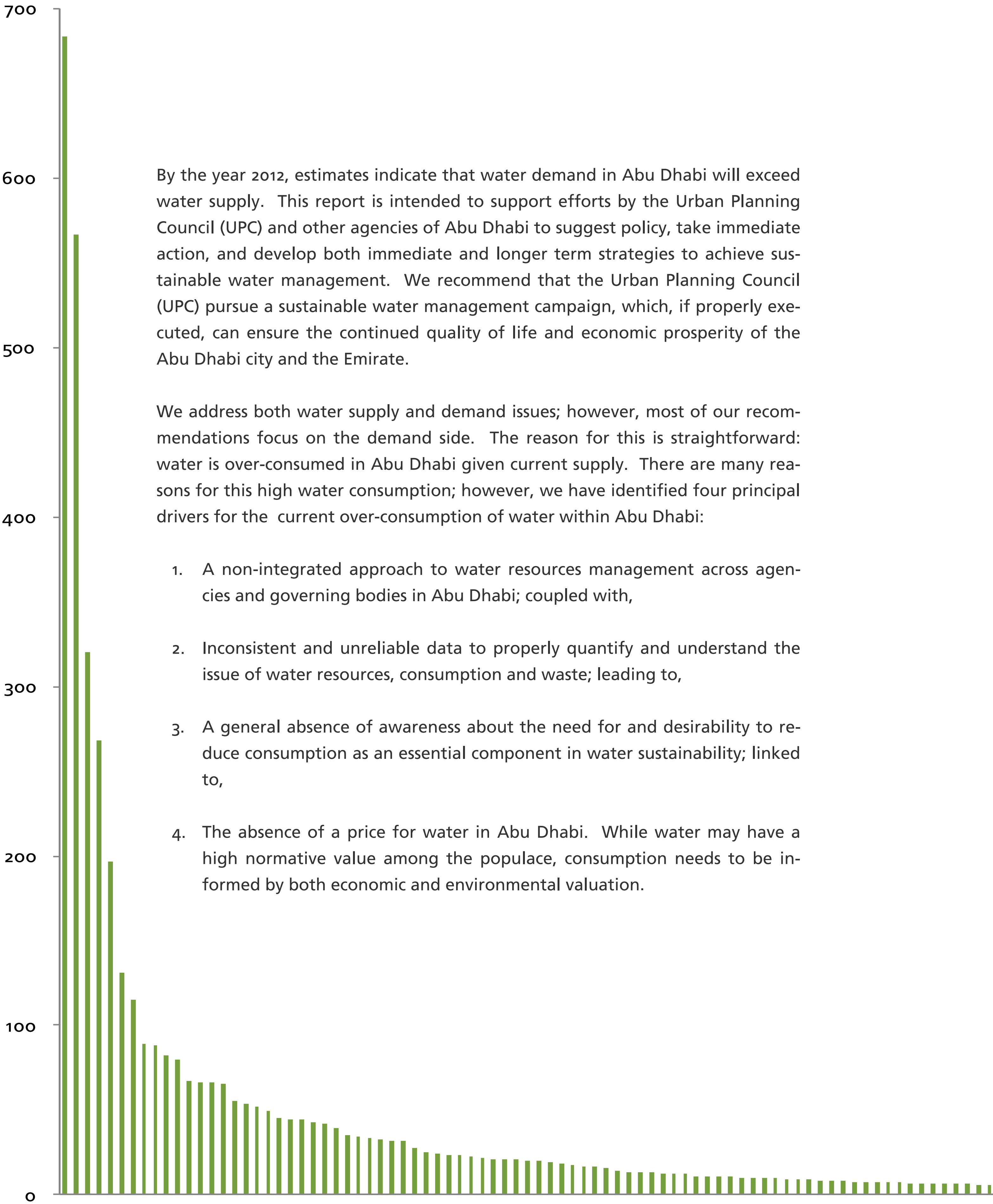


Figure 1. Average per capita renewable freshwater resources of more than 180 countries (million liters/capita/year). (World Resources Institute, 2007).

EXECUTIVE SUMMARY

In response to those four principal drivers we developed four cornerstones in support of efforts to achieve sustainable water management in Abu Dhabi. We recommend that Abu Dhabi's governing bodies:

1. Build a cogent institutional framework for water management across all agencies and government bodies in the form of an Abu Dhabi Sustainable Water Council that has decision making and regulatory authority over all water management for the purpose of building and integrating a sustainable water system.

2. Develop a coordinated data management and communication system for water supply and consumption to ensure that the Water Council has accurate, relevant, and actionable data to effectively base, evaluate, and communicate sustainable water policies and strategies.

3. Ensure household-level water monitoring and metering within the water distribution network to maximize efficiency (identifying and repairing water leaks) and to guarantee accurate measurements of per capita consumption while providing residents information on their consumption levels.

4. Plan and execute a set of strategies, including pricing, to shift the social, environmental, and economic value of water.

The steps and strategies necessary to realize each of these four cornerstones form the basis of this report, which focus on policies and actions that can lessen consumption across four sectors of the water demand infrastructure: (1) the residential sector; (2) Abu Dhabi's public spaces; (3) the agricultural industry; and (4) the tourism industry. We identify strategies to reduce consumption that can be implemented in the short, medium, and long term (ranging from 12 to 24 months to five or more years), and we also recommend that these strategies be pursued concurrently. The principal strategies for each sector are highlighted briefly on the next page.

In a comparison of more than 180 countries and their average renewable freshwater sources, the United Arab Emirates ranks second from the bottom with 31.4 m^3/capita/year.

1. **The residential sector represents the most important setting for reducing per capita demand of water.** The two most important strategies for achieving meaningful reduction in the residential sector are:

    - Immediately (within 1 year) begin a mass media campaign that has a clear reduction target (we recommend a consumption level of 250 liters per capita per day) and clear metrics to measure progress towards that goal. The campaign should be both top down and bottom up, using both high profile public and religious figures as well as new media to inform the Emirate on the water scarcity issue, and the steps individuals can take to reduce their water consumption.
    - In the short to medium term (within 1 to 3 years), deploy a suite of behavioral inducements and mandates to incentivize water consumption. Such efforts must include pricing water consumption (the removal of water subsidies), regulating car washing and villa landscaping, and giving residents clear feedback on their level of water consumption relative to their neighbors, which has been proven to be a powerful inducement in reducing electricity consumption.

2. **Abu Dhabi's public spaces are major consumers of water.** A mix of new landscaping and urban planning strategies can continue to make the Emirate and the country's capital an attractive, sustainable destination while providing the public and visitors a platform to showcase the Emirate's sustainability efforts. The three most important strategies for reducing water consumption in public spaces are:

    - Immediately (within 3 months) shift the irrigation timing of all public spaces so watering occurs before 0900 or after 1900 to prevent unnecessary evaporation. In the medium term (within 1 to 3 years), all public spaces should employ greywater as the principal means for all urban irrigation.
    - In the short to medium term (1 to 5 years), convert all public spaces into sustainable ones, removing water intensive plants and landscapes and replacing them with "xeriscapes" (indigenous plants and low-water landscaping techniques), increasing hardscaping (the use of non-plant landscapes), and reducing the number, size, and volume of public fountains.
    - In the short term (within 1 year), Estidama should create a sustainable landscaping guide so all public and private spaces within the Emirate can eventually be converted into water sustainable spaces.

3. **The agricultural industry is the economic sector with the highest total water consumption (64% of all groundwater and 45% of all water in the Emirate), while contributing less than 2% to the gross domestic product (GDP).** Further, the Emirate is not reliant on the agricultural sector for food security. Thus, despite the entrenched interests of those involved in agriculture, the sector represents a tremendous opportunity to reduce overall water consumption. We identify one main strategy focusing on increasing agricultural efficiency and reducing the extent of agriculture to be pursued in conjunction with the Emirate's strategy of reducing agricultural subsidies:

    - In the medium term (within 2 years), establish agricultural innovation and extension centers responsible for developing water conservation techniques and sharing them with farmers, to include using treated wastewater as a viable means for irrigation.

4. **The tourism sector can be effectively regulated to ensure water sustainability.** We recommend two strategies to reduce demand within the Emirate's hotels, making Abu Dhabi a sustainable destination for visitors:

    - In the short to medium term (within 1 to 2 years), incorporate the Pearl rating system into the criteria for hotel star ratings, ensuring that all highly rated hotels are as environmentally sustainable as possible.
    - In the medium term (within 3 years), a suite of incentives in the form of mandates and rebates should be deployed to ensure all hotels and tourist sites adopt water efficient technologies. Mandating hotel greywater systems and landscaping regulations will reduce consumption, as well as providing rebates for adopting water efficient technologies, such as toilet retrofits and low-flow showerheads.

No one strategy alone is sufficient to address the long-term water shortfall that Abu Dhabi will face if demand outpaces supply in 2012. One of the most important steps the Emirate can take is to make sustainable water practices among the highest priorities of its human, social, and economic development. From this perspective, a comprehensive and fully integrated approach to water management can emerge as a driver of economic growth and well-being for Abu Dhabi and the Emirate well into the 21st century. Reduced water consumption across all sectors is neither the sign of stagnated growth nor a weakened economy; rather, such a reduction can become the engine for a new type of growth, one that is indefinitely sustainable. Likewise the work of the UPC and other agencies in the Emirate can serve as a model for the region and position the UAE as a world leader in economic and environmental sustainability.

BACKGROUND

INTRODUCTION

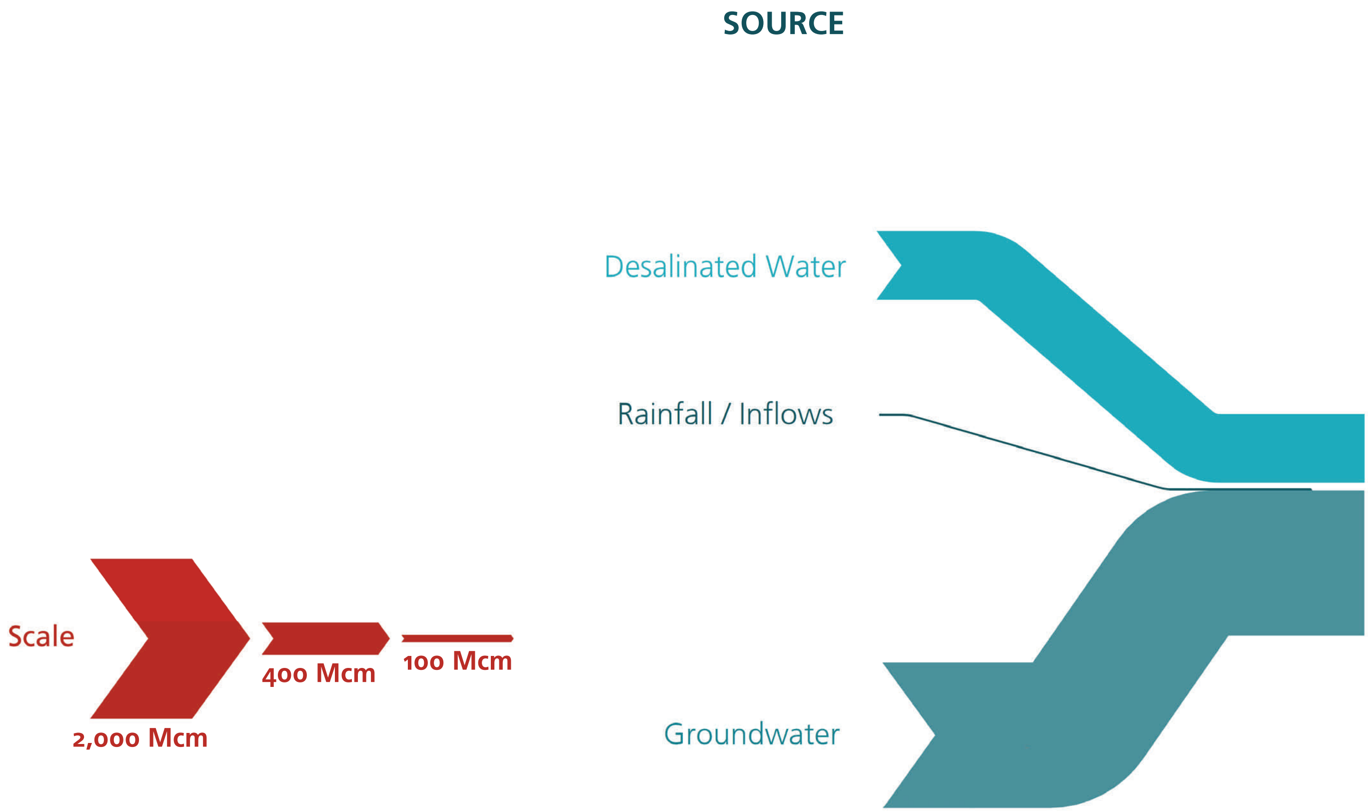
Freshwater is not distributed uniformly in space, time, or quality. And it is with this inconsistency that our problem begins, making water, in the words of Thomas Arnold, a 'complex social good,' with "meanings as varied and complex as the uses to which [...it] is put."[1]

The imperative for a government to ensure adequate water is both moral and economic, as water's role in sustaining and developing a country is fundamental, representing the foundation for its cities, highways, telecommunications, and economic potential. How a government moves to solve issues of freshwater scarcity is a function of how it describes them. An assessment of a region's water balance provides a low-resolution description of the physical (non-)presence of water—it only describes supply, often poorly. Such a description says nothing of demand or of the processes that inform demand; perhaps most importantly, it does nothing to highlight the interaction between water's demand and its supply. Arid Middle Eastern nations are right to ardently pursue strategies of supply, siphoning the great Arabian Gulf's water and removing its salt to provide to their people. But an overreliance upon supply-side solutions highlights a failure to disaggregate the interactions between water's supply and its attendant demand, as well as the impacts of such supply-side strategies. Disaggregating such interactions is challenging, and can prevent policymakers from developing lasting solutions to water scarcity. The solutions that rest at this nexus of supply and demand are the substance of this report.

By 2012, the Arab Emirate of Abu Dhabi will have an acute water shortage. Compounding this problem are anticipated increases in water demand, a function of the Emirate's tremendous economic and human development. It is, paradoxically, this explosive growth's interaction with water supply that could, in turn, begin to hinder the Emirate's future development. Abu Dhabi is uniquely placed because of its wealth and development: because it is one of the Middle East's most important economic centers, the issue of water scarcity represents both a bulwark and opportunity for the Emirate. Water scarcity gives the people and government of Abu Dhabi occasion to show the United Arab Emirates, the region, and the world the very model of sustainable development. It is this model of sustainability that will make the Emirate a leader in the field that will allow it to enjoy environmentally sustainable economic growth.

The Vision 2030 plans signal both that Abu Dhabi recognizes the opportunity that water scarcity represents and that it is willing to take the important steps to realizing its vision of a sustainable model of growth. Therefore, in order to deliver upon the vision of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the UAE, Ruler of Abu Dhabi, for the continued fulfillment of the grand design envisaged by the late Sheikh Zayed bin Sultan Al Nahyan, and the ongoing evolution of Abu Dhabi as a global capital city and Emirate, Abu Dhabi must develop a comprehensive set of sustainable water management policies.

The aim of this report is to help inform the shape such policies will take and the steps necessary to allow the Emirate to deploy meaningful and lasting water management solutions.

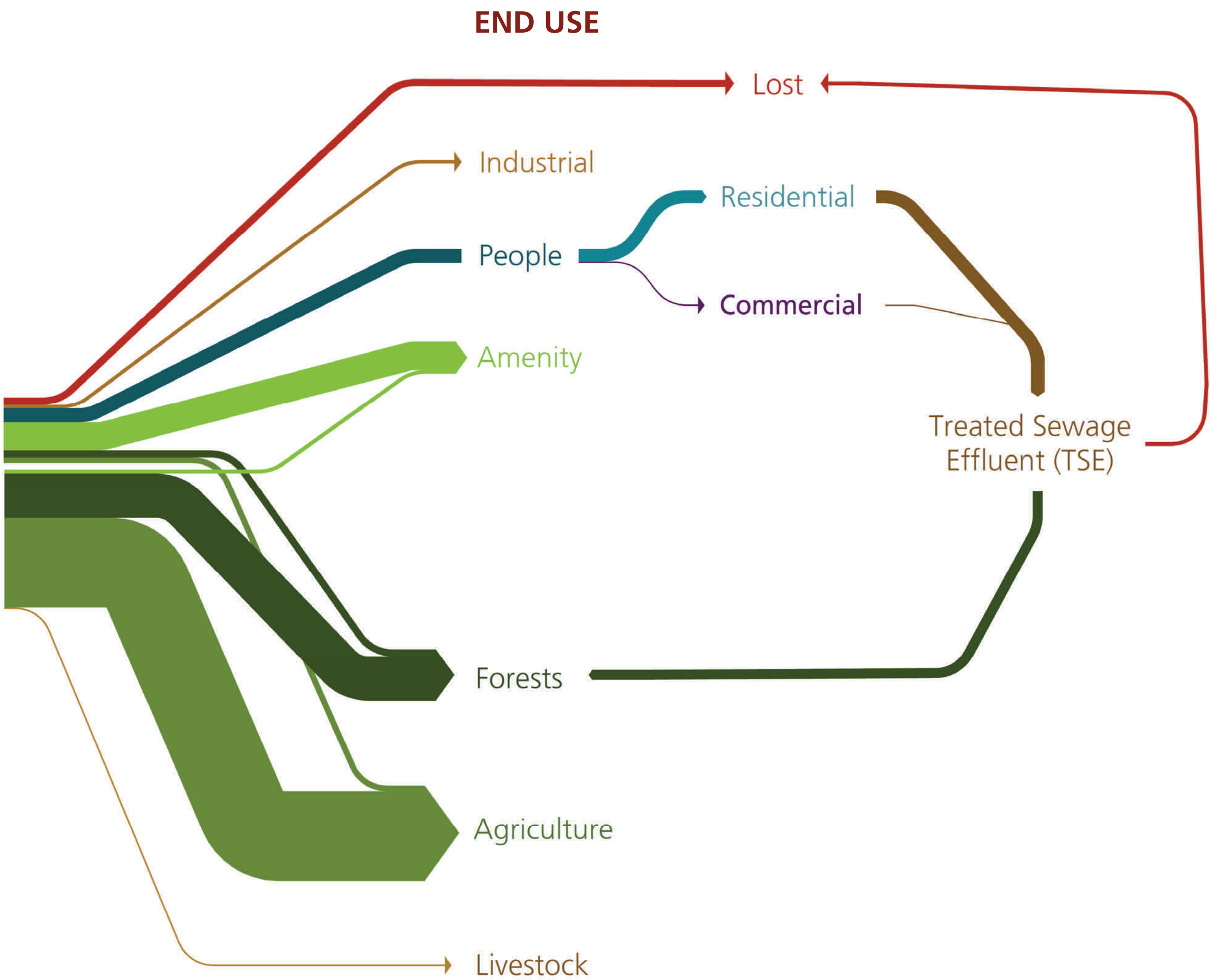


WATER SOURCES OF ABU DHABI

Abu Dhabi derives its water from two major sources: groundwater and desalinated water from the Arabian Gulf. Water from these sources is used for various purposes and the function of this section is to provide a proportionally accurate schematic of water from origin to end use.

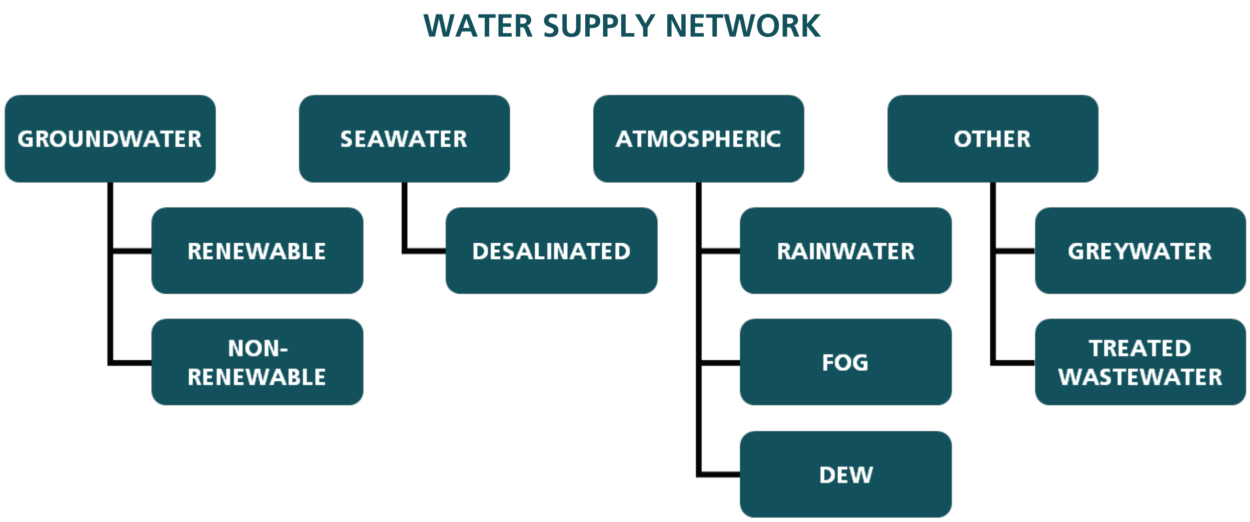
GROUNDWATER

Groundwater is comprised of water historically stored in the ground and the rainfalls / inflows that restore those reserves. A total of 1,816 Mcm of groundwater are used every year in Abu Dhabi.[2] The vast majority (96%) of groundwater is used for agriculture (64%) and forestry (32%), which also makes them opportune sectors for targeting water conservation strategies.[3]



DESALINATED SEAWATER

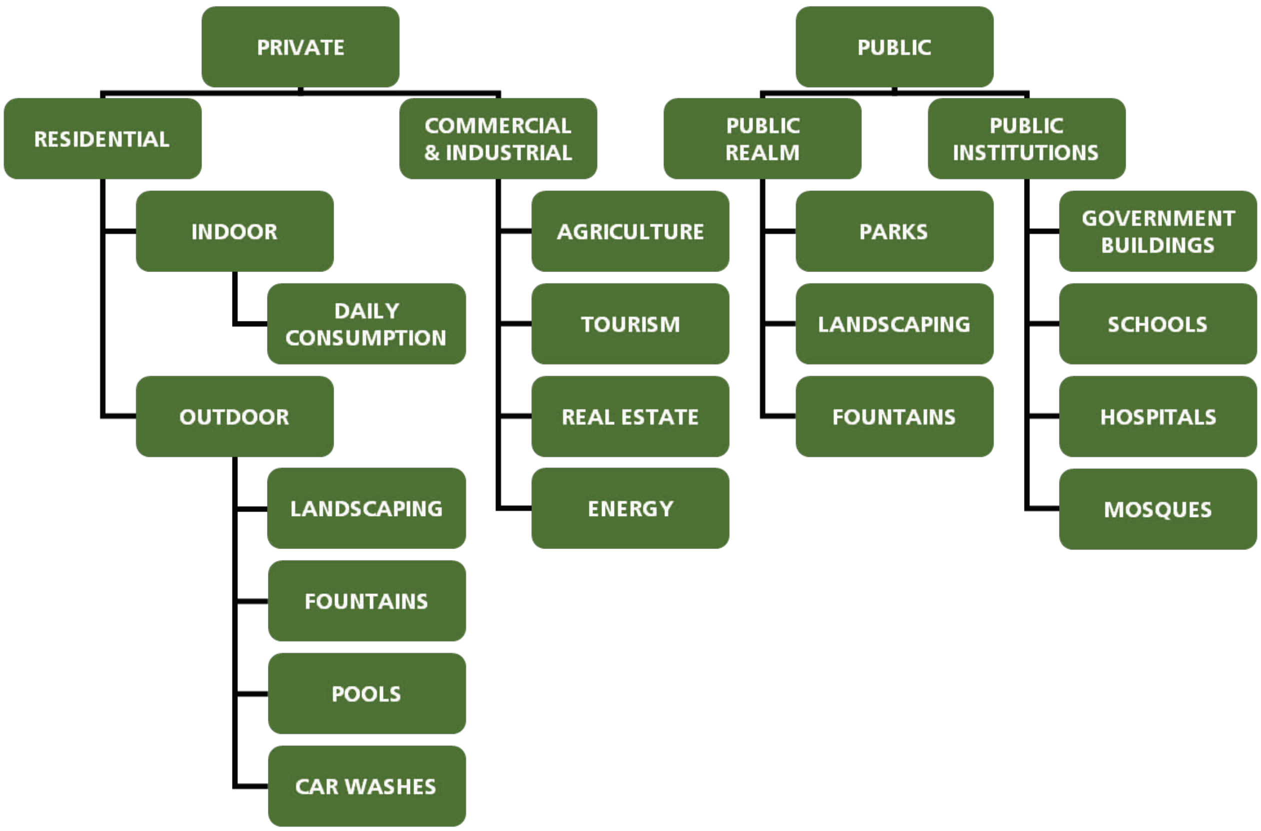
Desalinated water accounts for roughly 36% of the Emirate's total water supply. Eighty-three percent of desalinated water (856 million cubic meters (Mcm)) comes directly from desalination plants while the remaining seventeen percent (182 Mcm) comes from water reuse via treated sewage effluent.[4] Interestingly, people use only 183 Mcm (21%) of desalinated water, while 366 Mcm (42%) of desalinated water is used solely for amenity irrigation, another 91 Mcm (11%) is used for forest irrigation, and 76 Mcm (9%) is used to irrigate agriculture.[5] These high levels of consumption for vegetative irrigation present great opportunities for strategic water conservation efforts that may boost potable water supply for residents of Abu Dhabi.



ABU DHABI'S WATER SECTOR

Based on information collected from personal interviews conducted by the team with government agencies and organizations in Abu Dhabi as well as extensive background research, the team has created visual diagrams of the organizational structure of Abu Dhabi's water demand and supply sectors.

WATER DEMAND NETWORK



For the team, these water sector charts have been helpful in gaining a visual understanding of how Abu Dhabi's water sector is apportioned across its supply and demand networks. Using these diagrams, we were able to pinpoint the areas in which to focus our demand-side management policy recommendations and at the same time discern how these components fit within the overall picture of the Emirate's water sector.

The figures presented above are neither comprehensive nor definitive. Rather, the intent of this endeavor was to provide to the UPC or other water authorities in Abu Dhabi a useful foundational tool to be adapted and built upon for strategic sustainable water planning and policymaking purposes.

Salinity Zone Fresh (<1500 mg/l)	Area ($m^2 \times 10^6$)	Avg. Saturated Thickness (m)	Average Specific Yield	Volume in Storage (Mm^3)
Fresh - Eastern Region	1440	20	0.14	4,000
Fresh - Western Region	2400	26	0.23	14,000
Fresh - Emirate	3840	-	-	18,000
Salinity Zone Brackish (>1500 and <15,000 mg/l)				
Brackish below Fresh Water - Eastern Region	1440	40	0.14	8,000
Brackish below Fresh Water - Western Region	2400	69	0.23	38,000
Brackish - Remaining Areas	29,983	42	0.15	189,000
Brackish - Emirate	-	-	-	235,000
Total Fresh and Brackish Groundwater				253,000

Table 1. Groundwater reserves estimate for the Emirate of Abu Dhabi (USGS 1996).

Catchment Flow within UAE Abu Dhabi Emirate (Mm^3/yr)		
Catchments	Surface water runoff (wadi flow)	Groundwater (through flow)
	(Mm^3 / yr)	
Sumayni	0.2	1.4
Safwan	1.5	2.6
Musaydirah Kahal	1.4	1.9
Al Wadiyain	0.6	4.7
Hamad	1.9	1.1
Ajran	0.0	1
Sifah	0.0	2.6
Sharri	0.0	2.3
Al Fatah	2.1	2
Dank	0.0	7
Sawmahan	0.0	2.6
Al Hawl	0.0	1.6
Total	7.6	30.9

Table 2. Catchment flow within the Emirate of Abu Dhabi (USGS 1996).

ENVIRONMENTAL IMPACTS

THE QUANTITATIVE AND QUALITATIVE IMPACTS OF GROUNDWATER DEPLETION

The UAE's renewable freshwater supply is the second lowest in the world; simultaneously, the UAE ranks among the countries with the world's highest per capita residential demand for water.[6,7,8] Current estimates indicate water use for both human consumption and production is some 26 times the total annual renewable water resources available from groundwater.[9] Abu Dhabi's reliance on desalination for potable water is heavily driven by the decreasing water table and the subsequent deterioration of the remaining groundwater reserves.[10] Unsustainable consumption patterns in Abu Dhabi have resulted in permanently dewatered reservoirs. Further, in a region receiving less than 120 millimeters of precipitation annually, aquifer recharge rates are too low to offset the Emirate's annual water withdrawal.[11] In the Eastern Region for example, on the slopes of the Al Hajar Mountains, rainfall generates an average annual surface water flow of about 7.6 million cubic meters (Mcm). This runoff produces a natural recharge of groundwater estimated to be about 30.9 Mcm per year.[12] The freshwater area from Al Ain to Al Saad has lost 142,000 hectares since the 1980s. In the Liwa crescent area, the reduction is about 5,100 hectares.[13] At current extraction rates, the Emirate's fresh and brackish groundwater resources will be exhausted in 50 years.

Over-extraction of groundwater has produced probable irreversible effects in the Emirate's groundwater reservoirs: (1) there has been significant country-wide declines in the water table, with upwards of 47% in the northeastern region; (2) this reduction has caused significant saline intrusion into groundwater reserves, where extracted water is replaced by intruding brackish or saline water; and (3) has decreased water quality due to increased concentrations of chemicals and pollutants, predominantly fertilizers from contiguous farms. Concentrations of chromium, boron, and fluoride present in water samples taken throughout the Emirate exceeded the World Health Organization's (WHO) standards. When testing for nitrates, 80% of the sampled areas exceeded WHO guidelines, presenting significant economic and public health challenges for the Emirate.[14] Beyond causing myriad health problems if consumed by humans, this polluted water can have a crippling effect on livestock and place high stress on natural vegetation and fragile ecosystems. Unsustainable use of groundwater greatly increases the cost of further water extraction for existing and new water well users—farmers and rural communities outside of the desalination infrastructure. The increased energy and purification requirements of reduced groundwater pumping may make extraction unviable for many rural communities in the near future.

THE ENVIRONMENTAL IMPACTS OF DESALINATION

Desalination represents the single most important source of potable for the countries of the Arabian Gulf. Though desalting water is theoretically simple, the process of doing so at scale is complex, imposing significant capital, energy, opportunity, and environmental costs. Because of these costs, desalination sits atop a tension point: there is a great imperative to rapidly increase desalination capacity to ensure water's uninterrupted supply; there is also the imperative to ensure that its costs are also sustainable. Both desalination's place of importance and the future hope it represents for the Gulf makes it a key site for discussion about water supply and how such supply can be reconciled with notions of sustainability. Given the primacy of sustainability in this report, this section aims to highlight the environmental/economic considerations of desalination and suggests that an overreliance on the technology may in the long term be problematic within the overall objectives of sustainability.

The environmental impacts of desalination are often not monetized, nor are they well understood.

What is more apparent, however, is that economics alone cannot serve as a means to value earth functions, for valuation, "is neither necessary nor sufficient for conservation."[15]

For many regions, water management becomes a tradeoff of short-term gains at long-term losses and nowhere is this more salient than with the environmental costs of desalination, the most costly of which are detailed in this section. Properly valuing the costs of desalination would need to include valuations of ecosystem services, which are not easily valued through markets. Complicating efforts to evaluate the environmental costs beyond markets are issues of quantifying the effect of desalination itself. Impacts vary among plants, a function of the unique hydrography and biology of the site and the mix of technologies used. Broadly, desalination has two major sources of environmental costs: intensive energy use and ecosystem degradation from the brine discharge.[16]

THE ENVIRONMENTAL COSTS OF ENERGY

The discussion on desalination is dominated by the energy inputs required by the technology as a function of costs, and rightfully so. With a theoretical minimum of 0.7 kilowatt hours (kWh) of energy required to desalt a cubic meter of water (not including ancillary requirements, such as pumping), the process is doomed to be expensive.[17] A crude back-of-the-envelope calculation reveals the huge potential in energy consumption desalination signals: using year 2000 data, desalination consumed 2% of total world energy, some 8.5 exajoules (10^{18} joules), for a mere 15,000 plants worldwide.[18]

The energy required for desalination varies depending on the type of technology used, feedwater properties, pre- and post-treatment processes, and water pumping needs. As such, there are wide ranges for energy use, even when the same technologies are used. The amount of energy necessary for desalination increases with water salinity; thus brackish water requires less energy to desalinate than seawater.[19] Thermal processes generally require more energy than reverse osmosis; their energy needs range from 5 to 58 kWh/m^3.[20] However, given the prevalence of electric-desalination cogeneration plants in the UAE,[21] their energy use is lower, between 2 to 6 kWh/m^3.[22]

Desalination's primary environmental costs are a product of electricity requirements, which have environmental consequences all their own, most notably, contributions to aggregate greenhouse gas (GHG) emissions. Electricity generation from fossil fuels emit a variety of chemicals including carbon dioxide, nitrogen oxides, and sulfur dioxide, each of which causes numerous environmental impacts; although, the natural gas on which the Emirate relies for desalination does burn more cleanly than traditional fossil fuels. It remains, however, that carbon dioxide—emitted from the burning of fossil fuels such as natural gas—is the chief cause of climate change, which can have significant impacts on human health, food and water resources, and biodiversity. Sulfur dioxide, which is emitted when sulfur-containing fuels such as coal or oil are burned for electricity, is a leading cause of acid rain and can burn the leaves off trees and acidify waterways.[23] Nitrogen dioxide, which also contributes to acid rain, is a major contributor to smog, which damages forest, plants, and crops.[24]

These environmental impacts are global in scale and challenging to incorporate into traditional cost-benefit analyses of desalination. However, low-impact desalination technologies are being developed rapidly, and the UAE is uniquely positioned to be at the forefront for both investment in and utilization of such technologies, setting a template for the region and the world. Renewable energy-powered desalination systems are being extensively explored as well as mixed combination systems, such as a hybrid wind -solar photovoltaic reverse osmosis electrodialysis (RO-ED) brackish water system,[25] which could be ideal for desalting the Emirate's inland brackish groundwater.

A feasibility study conducted in Germany on wind-powered seawater desalination through both the mechanical vapor compression (MVC) and RO processes resulted in a potential product cost of 4.04 to 5.50 Dh, given ideal site placement and system performance.[26] Another study, conducted by Fernandez-Lopez (2009) in Spain, analyzed the economics of a coupled multi-effect distillation (MED) and MVC seawater desalination system powered by wind turbines and thermal solar collectors. The objective of this study was to completely separate the salt from the seawater in order to obtain a secondary end product with economic value to further improve the viability of the project as well as remove the environmental impact concerns related to brine concentrate discharged as a byproduct of desalination. The study found a final potential product cost of 3.08 Dh/m^3).[27]

THE ENVIRONMENTAL COSTS OF DESALINATION BRINE

The concentrated chemical composition of desalination brine discharge can cause significant environmental issues due to its differing salinity, temperature, heavy metal content, and concentration of other chemicals relative to the receiving water body. Generally 20-50% of the initial water becomes a salty by-product of desalination.[28] Because it can be as much as 2.5 times as saline as the original source, the brine has a very high density and may sink rather than disperse.[29]

In the UAE, where the prevailing desalination technology is thermal, it is difficult to characterize the behavior of the brine plume in the Arabian Gulf without empirical observations at the site in question. Intervening variables contributing to density are temperature and salinity: higher temperatures are positively buoyant, higher salt contents are negatively so. Given that the UAE's brine is high in both, the two may offset each other, rendering the plume neutrally buoyant. Further complicating this characterization is the year-round thermocline[30] on the UAE's coast and its shallowness. Thus, the plume can sit atop the thermocline, but may do so at a depth that still affects the benthic communities that provide the foundation for the delicate ecology in the Gulf, if the water is shallow enough. Eventually, the plume will cool and it will sink, settling on the bottom only to be mixed slowly. It is here, at the bottom of the Gulf, where the communities that dictate the ecological structure of the Gulf reside. Marine species only have a minor degree of adaptability in response to changes in the chemical composition of water, and these adaptations are usually gradual. The rapidity of the change in optimal conditions that desalination represents means that species have little time to adapt, disrupting the community structure, potentially rendering the seabed and the layers of water above, lifeless.[31]

A further complication is that brine from multi-stage flash (MSF) carries high concentrations of heavy metals, which can contaminate the area and bioaccummulate in the marine food chain. Table 3, below, summarizes some of the principal constituents within the brine plume.

Effluent parameter	Reverse Osmosis (RO)	Multi-stage flash (MSF)
Salinity	60-70 psu*	roughly 50 psu*
Temperature	Ambient	+ 5-15 C above ambient
Plume density	Negatively buoyant (sinks)	Positive, negatively or neutrally buoyant
Anti-scalants (e.g., polymaleic acid)	1-2 ppm	1-2 ppm
Acid (H_2SO_4)	pH 6-7	pH 6-7
Anti-foaming agents (e.g., polyglycol)	not used	0.1 ppm
Heavy metals (varying concentration)	Iron, chromium, nickel, molybdenum	Copper, nickel

Table 3. Effluent properties of RO and MSF plants. (Adapted from Lattemann and Höpner, 195)
*practical salinity units (psu) are a unitless ratio of salinity. Salinities above 45 are highly correlated with lower species diversity.

The brine discharged from a plant is twice (or more) as salty than the intake water, depending on its efficiency of production. It is also 15 degrees Celsius over the ambient temperature within the Gulf. Other nutrient loads are up to two or three times as concentrated in the brine as in the intake water, such as chloride and sulfates. Heavy metal contaminants, such as copper, nickel, and iron, are unique to MSF and accumulate in ecological food chains and disrupt the basis of local marine ecosystems by changing the phytoplankton communities.[32] Anti-foaming and anti-scaling additives for pre-treatment end up in the brine as stable toxic compounds and carcinogens adding to the chemical constituents of desalination brine.

THE GULF'S DESALINATION CARRYING CAPACITY

As of 2005, the combined seawater desalination capacity in the Gulf countries exceeds 11 million cubic meters (Mcm/day), between 45% to 58% of world capacity. It has grown substantially since then with planned and newly constructed plants. Saudi Arabia, Kuwait and the UAE have the largest installed desalination capacity in the Gulf with a production of about 1.8 km^3/yr.[33]

Desalination plants dot the Emirati coast in the southern Gulf, which is the shallowest portion of the water body. The depth and geophysical properties of the Gulf basin are important considerations in the analysis of brine plume impacts.

The Gulf is a shallow sea with a mean depth of 35 meters (less than 100 meters at its deepest), and its unique bathymetry and chemical composition govern the rate of brine plume distribution into the wider sea.[34] It covers an area of about 240,000 km^2; 1,000 km in length and breadths ranging from 185 km to 340 km.[35] The Strait of Hormuz, its only link to the greater ocean, is narrow, some 50 km at its narrowest. The sea has a volume of 8,630 km^3.[36]

Water flows	Volume	Depth equivalent
Total volume	roughly 8,600 km^3	
River discharge	35-133 km^3/yr	0.2 m/yr
Surface inflow at Hormuz	7250 km^3/yr	
Deep outflow at Hormuz	6620 km^3/yr	
Net evaporation	roughly 350-800 km^3/yr	1.67± 0.39 m/yr
Industrial discharges	>7.3 km^3/yr	0.02 m/yr

Table 4. Water balance of the Arabian Gulf basin.
(Adapted from Sheppard et al., "The Gulf: A young sea in decline," 2010, 16.)

Because of evaporative rates relative to depth, there are naturally higher salinity and sedimentation rates along the Trucial Coast, which is also the shallowest region of the Gulf. The Gulf already borders on hyper-salinity, and salinity increases in a non-linear regime, meaning that threshold effects of salinity are difficult to predict. Seawater entering the Gulf stays within the basin for about 2.5 to 5 years before returning to the Gulf of Oman.[37]

The Gulf's unique bathymetry and its waters' lengthy mean residence time interact with the region's reliance on it as a source of seawater for desalination. This interaction points to the possibility that the Gulf may have finite capacity to sustain expansion in desalination.

As desalination plants proliferate along the Gulf's coast, inputs of brine and temperatures will increase, exacerbating existing environmental degradation and increasing the costs of desalination in two ways: first, increases in temperature from the heated brine are correlated with algal blooms, which can cause a shutdown in desalination operations. Second, the saltier the Gulf's water becomes, the more salt that needs to be removed by the desalination process, thereby increasing costs. Because salinity and temperature increases generate non-linear impacts, predicting the Gulf's sustainability threshold will be a challenge. Further complicating this predictive work is desalination's interactions with other Gulf activity. From island building, coastal construction, oil spills, and other industrial inputs, sedimentation rates and other hydro-physical properties are under stress play a role in degrading the Gulf; thus, desalination impacts cannot be analyzed in a vacuum—it must include these interactions as well.

What is clear, however, is that the Gulf may be the victim of an emergent tragedy of the commons, serving as a proxy the overgrazed field or commons. Salinity and temperature inputs from increasing desalination capacity in other littoral countries could begin to affect the desalination regime in the UAE, and vice versa. Further, contiguous desalination increases could undermine conservation and other economic agendas on the Gulf, as the danger is that sufficient salt and temperature inputs within the mean residence time window could render the sea inert and unable to sustain life, affecting tourism and regional fishing economies. Regional cooperation on desalination capacities, therefore, can be an important platform for ensuring the resources of the Gulf for present and future generations and can bring about occasion for cooperation on other water issues as well.

Notably, desalination has yet to reach a non-linear regime where desalination inputs to the Gulf do irreparable harm. However, the possibility of breaching the desalination capacity of the Gulf remains and a proper model should aim to discover this threshold.

A regional governing body that both plans and coordinates state and substate efforts of Gulf desalination is highly recommended. The Gulf and desalination represent a classic tragedy of the commons, where no state has incentive to reduce their desalination capacity, but with continued increases in desalination plants, each country's efforts to supply desalinated water to their people will inevitably be affected by desalination in neighboring countries.

FUTURE SCENARIOS

Now that we have examined the existing sources of water in Abu Dhabi and the environmental impacts associated with using those sources, let us turn toward the future. Looking to 2030, there are three potential scenarios for water resource management in Abu Dhabi. The name of each scenario — Continuing Current Practices, Severe Decline in Supply, and Sustainable Water Stewardship — indicates how the variables impacting water use are assumed to change over time.

Assuming moderate population growth, reaching roughly 4 million people in Abu Dhabi, each of the three future scenarios give an idea of how water management practices in Abu Dhabi may have an impact on various indicators of water management.

Indicators of water management:

1. Water consumption per capita
2. Estimated annual desalinated water demand
3. Total groundwater reserves
4. Public awareness of water conservation

SCENARIO #1
CONTINUING CURRENT PRACTICES

Abu Dhabi continues on its current trajectory of water consumption and management. Residential consumption remains one of the highest in the world at roughly 550 liters per capita per day and the need for additional desalination, starting in 2012, increases proportionally. By 2030, Abu Dhabi has become a center for tourism and culture in the Middle East, spawning more major development projects including over eight times as many golf courses and demand for approximately seven times as many hotel rooms.[38]

Modest efforts to increase public awareness of water issues make an impact, but without incentives to change behavior, people continue their high rates of consumption. Though no new farm expansion due to regulations limiting agriculture growth, there are no incentives for farmers to reduce water consumption. Water information is sufficient, but difficult to access, even for decision makers.

SCENARIO #2
SEVERE DECLINE IN SUPPLY

Years of intense growth and irresponsible management raise the marginal cost of pumping groundwater and processing desalinated water to a cost-prohibitive level. The government is forced to make the difficult decision to institute severe rules on water consumption and enforces the new laws with strict fines. Because of the limited supply of water, residential consumption decreases to roughly 180 liters per capita per day, similar to other countries in the region with lower quality of life.

Public awareness efforts were low prior to the restrictions and, although people respond to the new incentives, many people may now view them negatively; these are now developed in a framework of crisis. Moreover, the possibilities exist that despite a concerted effort to educate the public on the importance of water conservation, penalties are seen as a means of generating additional revenue for the Emirate rather than a means toward sustainability. The uncertainty caused by the over-use of these natural resources leads to stagnation in economic growth and companies that once considered opening in Abu Dhabi now look to other cities.

As the costs of generating potable water increased, the government had to remove all subsidies toward agriculture and, coupled with the higher cost of pumping groundwater, the sector is quickly falling apart. Water information is gathered and shared amongst decision makers yet, there is little historical data and public perception of water data collection is guarded.

SCENARIO #3 SUSTAINABLE WATER STEWARDSHIP

The government leads the way and by shifting public awareness of water consumption through education, strategic public awareness campaigns, and less consumptive public works. People begin to reduce water consumption because of their desire to do the right thing for the country and also because they are encouraged to conserve by the government and their peers, through both positive and negative incentives. Abu Dhabi establishes itself as the leader of sustainable water management in the region while maintaining its robust economic and cultural growth. The government actively encourages water conservation in all sectors via funding for research and best-practice sharing.

Incentives guidelines are established for reduced water consumption in all government buildings and incentives are devised to decrease water consumption in all sectors. Water information is consistent, reliable, and shared with the public. In this scenario, Abu Dhabi becomes a mature water economy, where demand is met through the better use of existing supplies rather than the continual development of new supplies.[39]

VISION FOR WATER MANAGEMENT IN ABU DHABI

These three scenarios are all realistic outcomes. While a few variables affecting the likelihood of the scenarios are independent of decisions Abu Dhabi makes (e.g., climate change, market volatility), the majority of variables impacting future water scenarios are able to be influenced by decision makers. Thus, the likelihood of the above scenarios is mostly reliant upon the forethought and prudence of those in power, not chance. Decision makers currently have the opportunity to decide which future will become reality for Abu Dhabi. As a workshop team, we prefer and recommend that Abu Dhabi strive to achieve the third scenario, Sustainable Water Stewardship, because it has the most beneficial outcomes for the people of Abu Dhabi and for the region as a whole.

This report advances in three sections that will help guide Abu Dhabi toward achieving the goal of Sustainable Water Stewardship. First, we examine the keys to developing the institutional capacity for long term sustainable water management. Second, because demand-side management offers some low-hanging fruit largely independent of major technological advances, we recommend a set of selected policies for the near-term. Finally, we briefly examine some potential supply technologies and strategies that may prove worthy of further research.

INSTITUTIONAL RECOMMENDATIONS

INTRODUCTION

Abu Dhabi has been making great progress in implementing important measures toward achieving the goal of sustainable water management throughout the Emirate. In the long-term, in order for Abu Dhabi to continue making steps toward ensuring a sustainable future, we have identified the following four challenges that offer opportunities to develop institutional capacity to promote sustainable water management.

These four "keys" to sustainable water management are:

1. Creating a unified vision and governance
2. Developing a data management and communication system
3. Improving the water monitoring system
4. Establishing incentives for sustainable water use

1

UNIFIED COLLABORATION

A major hurdle to realizing a sustainable water future for Abu Dhabi lies in the present lack of a comprehensive institutional framework with sustainable water management as its primary objective. The establishment of the Abu Dhabi Sustainable Water Council (the Council), an inter-agency water council to act as a governing and overseeing body, needs to be a priority in the Emirate in order for Abu Dhabi to achieve the goal of sustainable water management.

Currently, various duties within the broad category of water management are spread across different government agencies and organizations with varying levels of scope, mission, and authority. These agencies may not be directly related to the water sector, but rather are indirectly involved, for example through building and urban development design, infrastructure planning, or through their involvement with closely associated sectors, such as electricity production. Consequently, these agencies perform their water management responsibilities as an obligatory side component of their main agency missions and not necessarily with sustainable water principles at the fore. This results in an unorganized and non-cohesive water sector that has great potential for sector-wide efficiency improvements and opportunities for cross-agency synergies.

ESTABLISHING AN ABU DHABI SUSTAINABLE WATER COUNCIL

To capitalize on this unrealized potential to develop a strong and sustainable water sector, a unifying governing body tasked with overseeing and guiding all developments in Abu Dhabi's water sector should be established. This governing body's explicit mission will be to build an integrated and sustainable water system within the Emirate. The Council will act to coordinate the disparate agencies currently involved in influencing water management in Abu Dhabi, while still allowing the agencies to have their own role in water management. This governing body, the Abu Dhabi Sustainable Water Council, will be comprised of key persons and senior level staff within agencies and organizations that currently play a role within the Emirate's water network.

A suggested list of water sector stakeholders to form the Emirate-wide Council:

- Abu Dhabi Distribution Company (ADDC)
- Abu Dhabi Sewerage Services Company (ADSSC)
- Abu Dhabi Tourism Authority (ADTA)
- Abu Dhabi Transmission and Despatch Company (TRANSCO)
- Abu Dhabi Urban Planning Council (UPC)
- Abu Dhabi Water and Electricity Authority (ADWEA)
- Abu Dhabi Water and Electricity Company (ADWEC)
- Department of Municipal Affairs (DMA), Abu Dhabi Municipality, Al Ain Municipality, and the Western Region Municipality
- Executive Affairs Authority (EAA)
- Environment Agency – Abu Dhabi (EAD)
- Masdar City/Masdar Institute of Science and Technology (MIST)
- Regulation and Supervision Bureau (RSB)
- Major real estate developers: the Tourism Development and Investment Company (TDIC), Al Dar, Mubadala, Sorouh, Royal Group, etc.

In the short term, the Council will convene regularly to develop a centralized and unified strategic plan for sustainable water management encompassing every component of Abu Dhabi's water supply and demand networks and involve all relevant agencies. The Council will initially carry out its strategic plan by assigning specific initiatives to the appropriate existing agencies to implement. For example, the Council will advise the Regulation and Supervision Bureau (RSB) on sustainable water policies or work with Masdar on sustainable water capture technologies.

The long-term goal of the Council will be to expand into a full-size agency containing both the strategic advisory council of water sector stakeholders as well as dedicated staff to enable the Council to carry out centralized initiatives in-house. Such long term initiatives include illustrating and monitoring water rates, providing daily water consumption reports, exploring new water supply technologies and demand reduction strategies, promoting public awareness campaigns, managing incoming streams of water data, monitoring water consumption in all sectors, and coordinating with other Emirates and countries in the region on water initiatives. The creation of the Council will allow Abu Dhabi to effectively manage the succeeding three identified "keys" (data management, monitoring, and incentives), as well as implement the specific recommendations outlined in this report.

KEY TASKS FOR THE WATER COUNCIL

A few suggested responsibilities of the Council are outlined below:

- **REGULATION:** Advise and guide regulatory development, e.g. provide guidance on specific regulations necessary or the level of detail to which regulations need to be promulgated by agency, incorporate sustainable water management into current and upcoming urban planning efforts, etc.

- **RESEARCH & DEVELOPMENT:** Collaborate closely with academic institutions and research projects, such as the Masdar Institute of Science and Technology (MIST) and the Masdar City sustainable urban development project, to transfer newly developed technologies and provide feedback on urban planning policies.

- **INFRASTRUCTURE:** Serve as the communicating body responsible for bringing together agencies currently involved with infrastructure and network planning to develop a water grid (storage and transport locations) within the whole Emirate.

- **PRICING:** In charge of advising the RSB on pricing rates with monitoring consumption as well as developing effective pricing strategies (penalties, fines, etc.) that will help consumers reduce consumption.

- **DATA MANAGEMENT AND COMMUNICATION:** Gather, monitor, and evaluate standardized data into one centralized database to provide comprehensive and accurate future projections for use by water sector stakeholders.

- **PROPOSING STRATEGIES:** Initiate continuous research and discussion of new demand and supply strategies, consider new policies regarding sustainable water management.

- **PUBLIC AWARENESS:** Coordinate all public awareness efforts across all agencies to make sure they are consistent, cohesive, and effective. Ultimately, the goal of this arrangement is to provide a planning and oversight body dedicated to sustainable water management with the ability to provide guidance to other agencies as well as the capability to perform centralized services essential to an integrated and collaborative water sector. Successful implementation of the Council can lead to the creation a National Water Strategy to oversee sustainable water management for not just Abu Dhabi but for the entire UAE.

2

DATA MANAGEMENT AND COMMUNICATION

A critical yet often overlooked facet of policy development and implementation is data management. Armed with sound data, decision makers are able to tailor effective regulations, such as quality standards, price points, permit caps, and tariffs. Without data, baselines from which to gauge current trends are inaccurate if not impossible to determine. However, simply having the data is not enough; decision makers also require integration, management, and communication.

A challenge to the existing water management system in Abu Dhabi is the level of data standardization and sharing among agencies throughout the Emirate. Currently, data are collected by several different agencies and housed in internal databases. With limited communication between the agencies, it is difficult to determine which data exist and which have not yet been collected. Since data collection can be costly, finding and sharing data can reduce government-wide costs while facilitating efficient planning and decision-making. Integration of data could improve development and implementation of water management policies in Abu Dhabi by enhancing the ability of agencies to achieve their missions through efficient and transparent Emirate-wide data collection.

The Council will play a key role in mandating the standardization of data and facilitating the dissemination of information to the relevant agencies and organizations. A potential strategy for overcoming the data challenge is to develop a data management and communication system to provide consistent, standardized, accessible, and reliable water data. Integration of data collected into one centralized system reduces redundancies in data collected. Also, the access to timely and accurate water data from an integrated system further allows agencies to be more efficient in creating and implementing policies regarding water management in Abu Dhabi.

Data management systems involve: implementing a standardized system for data collection, updating the information technology infrastructure to ensure the integration of data collected by different agencies, and allowing for sharing among them. To accomplish this, the following steps are often taken to implement the data management and collection system:

1. Establish an agency or entity to oversee the implementation of the system
2. The agency will establish protocols and standards for data collection, processing, management, and communication
3. Plan for integrating new technologies

Examples of current and historical data to include in such a system are water quality, water supply, precipitation, groundwater levels, permitting and licenses, consumption by unit or sector, and spatial data for infrastructure, zoning, property, and well locations.

If a centralized data management and communication system cannot be created, agencies may aim to increase the transparency of existing data. Even without a centralized system, agencies can make their data more accessible and easier to understand for other agencies to find.

3

WATER SYSTEM MONITORING AND METERING

In order to meet the water demand of Abu Dhabi's growing population, the water distribution network must be well managed and understood, from large water utility suppliers down to individual household connections. A strategic approach to water management should be able to track the movement of its commodity, water, down to the last drop. However, some of that liquid commodity inevitably escapes through leakages and wastage in Abu Dhabi's water distribution network.[40] Though leakage is a universal challenge for water managers, Abu Dhabi's growing need for water conservation creates an imperative to mitigate water loss through well-developed monitoring systems.

Baseline measurements of water distribution and current losses are a necessary initial step in leakage reduction. Currently, agency estimates of water loss range from 10 to 20% for Abu Dhabi.[41] Though loss within that range is comparable to industry standards, the exact amount of water loss should be accurately determined for the entire Emirate. Quantifying loss through monitoring would enable the government to identify where infrastructure and transmission improvements are necessary, particularly the Abu Dhabi Distribution Company, Al Ain Distribution Company, and Regulation & Supervision Bureau (RSB).[42] Monitoring how and where water is lost will assist in determining how water transmission infrastructure can be developed and better maintained to meet demand, thereby furthering the overall objective of Estidama and water conservation.

In addition to using monitoring to identify leakages, the RSB recognizes the opportunity to improve the performance of the water network systems through the use of metering. Effective smart metering can be used to save and better utilize water resources by monitoring both consumption and identifying leakage through accurate and comprehensive flow metering of distribution input and consumption volumes on a zonal basis. In 1999, the Meter and Data Exchange Code (MDEC), under the authority of the RSB, came into effect to define the minimum standard for interface metering between licensees. Unfortunately, licensees have been slow to upgrade their metering systems resulting in 35% of water meters failing to meet the defined MDEC standard. Currently in Abu Dhabi, the RSB is overseeing the implementation of smart metering throughout the Emirate. The RSB reported that over the past few years, both the Al Ain Distribution Company and the Abu Dhabi Distribution Company have been completing smart metering trials through installing electronic meters for automatic reading purposes.

4

WATER VALUATION

There is a failure to properly value water in Abu Dhabi. The cognitive dissonance between the reality that represents the Emirate's water scarcity and the way in which residents use their water in their day-to-day life is a significant hurdle for policy. Demand for water in Abu Dhabi has increased in recent years—a function of population growth, urbanization, and increases in per capita income. Between 2001 and 2006, the population grew by a compounded average of 4.57% annually.[43] And many of these new residents live lifestyles more suitable to temperate climates, adopting villas, swimming pools, and new vehicles. Per capita demand of water in the country has skyrocketed to be among the highest in the world, an estimated 550 liters per person, per day—compared to Jordan's 85 liters.[44] Inefficient practices such as watering gardens and washing cars use hundreds of liters of water at a time, engendering a perception of water as an infinite resource.[45]

There are myriad factors that have contributed to this perception of water wealth; in fact, it has been shaped in part by the explosive economic growth in the country and its interaction with the political status quo. The tremendous reliance on desalination to provide potable water serves to reinforce the myth of water plenty—many countries with analogous climates find desalination cost prohibitive. But the Emirate has the wealth and the interest in making water provision seem effortless; this appearance informs public perceptions of water's supply, and by extension, value. Just as being a leader in desalination has been integral to the Emirate's economic success, so too will being a world leader in water sustainability measures ensure the city's economic future.

There are complex interactions that make reducing water demand a challenging policy issue. The demographics of the Emirate's population—approximately 19% of Abu Dhabi's residents are Emirati with the remaining population consisting of other Arab, Indian and South Asian descent, including expatriates—intimate at the challenge of gaining all of Abu Dhabi's residents' buy-in for a sustainable future.[46] High water subsidies for nationals and the low cost to non-nationals have belied the real costs of water. Thus, one of the principal challenges in Abu Dhabi's effort to move toward a water sustainable future is that water is viewed as a right awarded by the state, not a commodity. Changing from one typology to the other can be painful politically; water issues in the United States and Australia have long been tools for political gain. But it remains that the current consumption patterns and the lack of a price signal on water do not motivate the Abu Dhabi population to reduce water usage.

Water must be treated as an economic good with value to effectively incentivize conservation; and water holds all of the necessary characteristics to do so: it is finite, essential, and non-substitutable commodity.[47] Water should be priced for two reasons. By reasonably pricing water, costs can be recovered to make improvements within the water infrastructure. The second benefit of pricing water comes through its signaling users that water has value and should be treated as a scarce resource.[48] By treating water as an economic good, it integrates cultural, political, societal, and environmental considerations in an overall water strategy rather than solely focusing on price.[49] However the economic value of water "depends on when, where and how it occurs"[50] as well as how it is to be used.

Consumer incentives, along with other strategies, are recognized as an integral tool to reduce water consumption. The Economic Affairs Unit of the Executive Affairs Authority (EAA) is currently developing programs in conjunction with various agencies to encourage consumers to reduce waste of water.[51] On the water pricing side, a progressive increase to water tariffs has been suggested, however it should be noted that the UAE has preempted plans to study tariff increases.[52]

1 UNIFED COLLABORATION CASE STUDIES

Santa Fe Water Division, New Mexico, USA[53]

A New Mexico government initiative was created to look at the pressing water issue in the oldest capital city of the United States, Santa Fe. In order to achieve New Mexico's water sustainability goals, the Santa Fe Water Division deals with the following:

- Strategies for water reduction
- Water quality, conservation and management
- Water transmission and storage system master plan
- Illustrate clear and concise water reports
- Public awareness campaigns on water reduction
- Pricing policies

These strategies are all within the scope of the division, below are some more detail on some of the strategies the Santa Fe water division is currently working on:

Pricing Policies

The division is looking at increasing water rates by 8.2% every year for the next 5 years. This aggressive pricing strategy is governed and implemented by the division itself. Under this pricing policy, the average residential monthly water increased from $31.51 (115.64 Dh) in 2008 to $34.10 (125.15 Dh) in 2009, $36.90 (135.42 Dh) in 2010 and so on. The pricing change is also applicable to commercial and retail users.

Water Transmission & Storage System Master Plan

The goal of this master plan is to advance and develop water transmission and storage components. With this master plan the division can clearly portray water demand/supply and help develop sustainable water strategies for growing populations.

The master plan provides:

- An overview of how the system could be assessed and improved with innovative design
- Existing and projected water demand database
- Supply strategies to meet water needs
- Calibrated hydraulic model of the water system
- Assessment of the current water transmission system
- Assessment of storage system and enhancements needed to meet projected water demands
- Overall improvements for storage and transmission systems

Water conservation and public outreach

The division has dedicated a website to demonstrate different strategies that could be used by Santa Fe residents to reduce their water consumption. One of the strategies is a demonstration garden showing and educating the general public on the use of native species, hardscaping and irrigation scheduling for more sustainable water practices. Other awareness campaigns include: fixing leaks, children educational awareness, tips of saving money on water bills and a water service hotline.

Most of the following strategies could be adopted in other cities with similar water situations. Both Abu Dhabi and the Santa Fe has serious water supply issues, Santa Fe's Water Division could be a model to the government institution that Abu Dhabi should invest in.

Queensland Water Commission, Australia[54]

The Queensland Water Commission was established in 2006, under the legislative framework of the Water Act 2000. The Commission is a self-governing, legislative authority responsible for attaining healthy and sustainable water supplies in South East Queensland and other selected regions. The goal of the commission is to provide sustainable water supplies by:

- Managing overall water demand and supply
- Creating long term and short term water supply strategies
- Implement water restrictions
- Design a regional water grid
- Advising other government agencies and departments on water related issues

With a significant role in water management, this young organization is currently working on several sustainable water initiatives such as developing a pipeline water grid by mapping out storage areas and transport mechanisms.

Other current projects include:

- Constant research and development on alternative water supply, such as rainwater harvesting, groundwater, dew capture and desalination
- Treating and recycling water for irrigation, commercial and industrial use
- Determining new water storage methods (building/retrofitting dams, etc.)
- Reduce leakage within major water pipes
- Retrofitting residential units with water reducing technologies

Moreover, the commission works on continuous sustainable water research creating publications on alternative water supply options, cloud seeding, groundwater extraction, urban stormwater harvesting and water saving technologies. The commission's website is continuously updated with water information that is easily accessible to other government agencies, private firms as well as the general public. Constant data management and sharing is crucial to reaching highest levels of sustainable water management. Communicating and coordinating between government agencies and continuous public awareness are key to a successful organization managing water issues.

Royal Commission of Water, Jordan[55]

The Ministry of Water and Irrigation (MWI), Jordan's main overseeing and implementing body for the country's water sector operations and policies, houses the Royal Commission of Water. The Commission, established by King Abdullah in February 2008, is comprised of various senior level staff including the Ministers of Water and Irrigation, Agriculture and the Environment, and the director of the Economic Department at the Royal Court and headed by Prince Feisal. The Council's main responsibility is to develop the country's water sector and establish a viable water management system.

Specific responsibilities include:

- Reducing Jordan's rising levels of unsustainable groundwater extraction
- Developing an efficient water resource management system to engender prudent water usage
- Expanding the country's current water storage capacity
- Ensuring equitable water provision to both individuals and corporations in order to meet residential, industrial, and agricultural needs
- Coordinating with concerned agencies on sustainable water management plans and projects
- Communicating with international field experts to explore alternative sources of water including desalination and water treatment technologies
- Amending relevant government legislation to build an institutional environment that will encourage the private sector to invest in sustainable water management

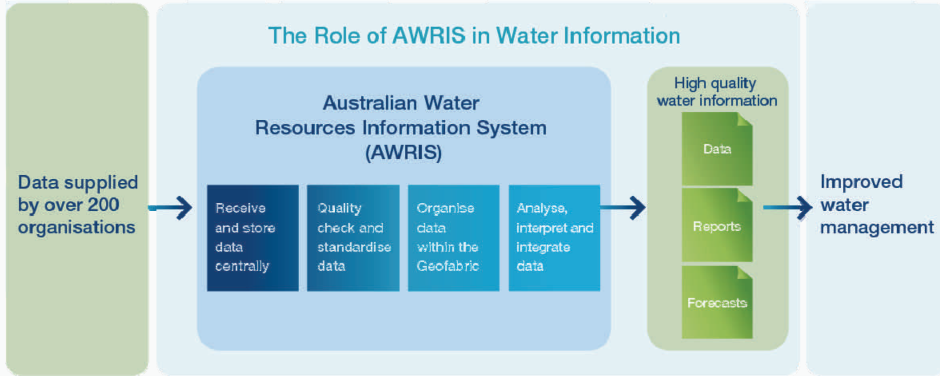
2 DATA MANAGEMENT AND COMMUNICATION CASE STUDIES

Australia

Australia is a good example of a country that is standardizing all of its water data and integrating it into one centralized system. In Australia, the Bureau of Meteorology (the Bureau) is responsible for gathering and disseminating water information among more than 200 organizations across the country. The Bureau receives standardized information (e.g., river flows and groundwater levels, water volumes in storage, water use and restrictions, water entitlements), and uses it to report on water availability, conditions, and use in a consistent format. In the past, water data in Australia was collected using a wide array of formats and standards. In 2008, the approved Water Regulations mandated specific water data collecting agencies to supply types of their water data to the Bureau to be used to in public reports and forecasts. The standardized and centralized data will lead to improvements in quality and efficiency of water management and policy making in Australia.[56]

The Bureau is also establishing a centralized database, known as Australian Water Resources Information System (AWRIS), to act as a means of disseminating the water data publically to all Australians. By combining historical data records with current observations, AWRIS is a data management and communication system capable of receiving, standardizing, organizing, and interpreting the water data collected from all over the country. In addition to being accessible by various agencies in the country, the data will be made available to the public through the web, mobile devices and hydrologic forecasting systems by the Bureau. The Bureau will use AWRIS to deliver water data, reports and forecasts including: historical and current water data that users can access, real-time water reports (e.g., storage levels and volumes), annual National Water Account assessments, seasonal forecasts, and improved flood warning systems.[57]

The first phase of AWRIS implementation has been completed and the Bureau is in the process of delivering the 2010 water information products and storage information. AWRIS will be implemented over a 10 year period, during which the capacity of AWRIS will evolve and enable faster access and more comprehensive data, reports and forecasts.[58]



(Australian Government - Bureau of Meteorology Information Sheet 3, Australian Water Resources Information System (AWRIS), http://www.bom.gov.au/water/about/publications/document/InfoSheet_3.pdf)

Jordan

The Ministry of Water and Irrigation (MWI) in Jordan is the body responsible for the overall monitoring of the water sector, supply, wastewater system and the related projects, planning, managing, and formulation of national water policies and strategies. The role of the MWI has the provision for the centralized water-related data, including the standardization and consolidation of data. Jordan is using technology to optimize its water management decision-making processes.[59]

Jordan has also recently implemented a data management in communication system with the launching of the digital National Water Master Plan (NWMP). The NWMP is an integrated plan that allows decision makers to set policies and strategies based on current and project future water consumption trends.[60] The NWMP is based on the Water Information System (WIS), which is the central database containing the country's monitoring field data related to water resources and demands.[61] The WIS is integrated data system containing Oracle Relational Database Management Systems (RDBMS) databases, geographic information systems (GIS) ArcView spatial databases, hydrologic analysis applications and the NWMP.[62]

In May 2009, King Abdullah announced the country's plan for a National Water Strategy to 2022 Through using the WIS and the NWMP, the National Water Strategy plan until 2022 tackles such measures are decreasing reliance on groundwater (from 32% to 17%), increasing use of TSE for agricultural purposes, and increasing use of desalination from (1% to 31%). In addition to using WIS to its fullest capacity, in order for this Plan to work, institutional reforms (such as creating a Water Council for advisory and establishing a Water Regulatory Commission) are necessary.[63]

India

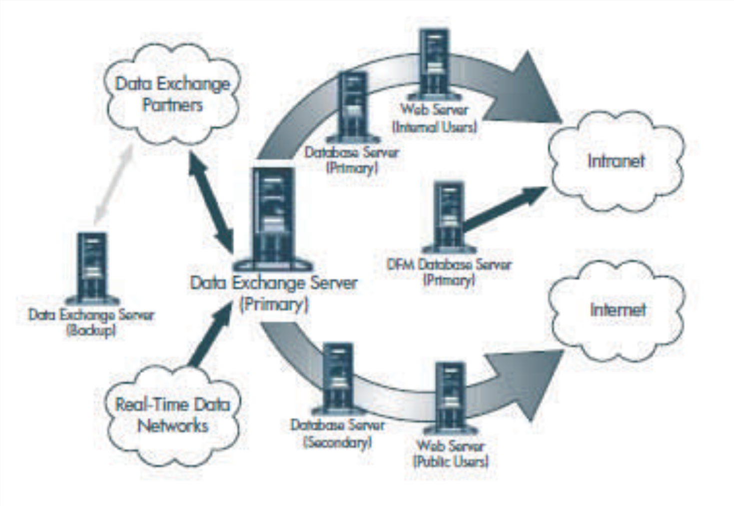
India has envisioned the integration of all of the country's databases into one warehouse, the Hydrological Information System, so that they can be disseminated to various users. In India, the Central Water Commission, which is under the authority of the Ministry of Water Resources, holds the general responsibilities of coordinating and furthering efforts in the conservation and utilization of water resources throughout the country for flood control, drinking water supply, irrigation, navigation, and water power development purposes.[64]

To aid in the creation of the Hydrological Information System, the Central Water Commission has created a centralized water data management and communication system accessible online called the Water Information System Data Online Management (WISDOM). WISDOM is available to different agencies/organizations and the public through the website http://www.india-water.com/index.asp. The scope of activities that WISDOM performs includes: data collection, storage, processing, exchanging, communicating, disseminating, analyzing, and reporting on.[65] The WISDOM website aims to facilitate the process of making hydrological data available to the user in an efficient and standardized format that allows for easy use and application.[66] It is a purpose-built software used for systematic storage and retrieval of various types of data. Meta-data available on the website contains information available from several surface and groundwater agencies in India. WISDOM currently holds the information of 28 Data Storage Centers (DSC) owned by 9 different states and is mainly used as an import and export vehicle for data transfer and exchange.[67]

Data users can view public domain hydrological information available on the site and also submit agency requests for data that may not be posted by the DSC. A Data Request File (DRF) can easily be filled out by the data user after he/she registers with the website and has a Login name and Password. A user must select appropriate parameters and sites that they are focusing on and then submit the DRF, which is disseminated to the appropriate DSCs pertaining to the respective agencies. Next, the user's eligibility is approved the DRFs are processed and invoiced for payment. Once payment is received, the DSC of the respective agency will make the data available to the user through their desired format (e-mail, soft copy, or hard copy).[68]

California, USA

In 1996, the U.S. state of California developed an internet database for storing and sharing historical, current, and forecasted hydrologic data.[69] Though many of the data are derived from physical sensors and gauge systems, the California Data Exchange Center (CDEC) successfully incorporates data from over 140 agencies at the local, state, and federal level.[70] Its data are used for forecasting water supply, planning studies, emergency response,[71] and infrastructure and are critical for agencies to predict water availability.[72] Data users are categorized as internal or external users and are privy to different data classifications accordingly.[73] Different users have different access levels, but the efficiency of the system and its ability to disseminate data lies in the fact that all data are housed within a single system with one access point.[74]



(CDEC Brochure, www.water.ca.gov/floodmgmt/docs/CDEC_Brochure.pdf)

3 WATER SYSTEM MONITORING AND METERING CASE STUDIES

Australia

In June 2004, the Intergovernmental Agreement on a National Water Initiative was signed at the Council of Australian Governments meeting. The National Water Initiative is a shared commitment by Australia's governments to increase the efficiency of water use in Australia. Leakage monitoring is found under the Demand Management portion of the Initiative. Under of this section, States and Territories agreed to undertake the following actions by 2006:

1. legislation to implement the Water Efficiency Labeling Scheme to be in place in all jurisdictions and regulator undertaking compliance activity by 2005;
2. develop and implement a 'Smart Water Mark' for household gardens;
3. review the effectiveness of temporary water restrictions and associated public education strategies, and assess the scope for extending low level restrictions as standard practice; and
4. prioritize and implement cost effective management responses to water supply and discharge system losses including leakage, excess pressure, overflows and other maintenance needs.[75]

State and Territory wide initiatives, like the Gold Coast Waterfuture Strategy, have also been put in place to aid in Australia reaching the mentioned goals above. The Gold Coast Waterfuture Strategy 2006-2056 has put forth several key initiatives to ensure the Gold Coast maintains a sustainable water supply over the next 50 years. In 2005, the Gold Coast Water's Pressure and Leakage Management program presented the plan to conserve drinking water by detecting and repairing leaks in the network, decreasing the potential of pipe bursts, and reducing the amount of water used in home. In just two years, by later 2007, the Pressure and Leakage Management Program had completed infrastructure components including 60 District- Metered Areas in Beenleigh, Coolangatta Benowa, Southport, Bundall, Labrador, Helensvale, Carrara, Yatala, Coomera and Nerang.[76] Currently six are only leakage managed, 18 are partially pressure reduced or not pressure reduced, and the remaining 36 are fully operational.

Arizona, USA[77]

According a document published by Northern Arizona University (2009) it is necessary to have a comprehensive water audit examining two main aspects. First, the audit should look at the utility's production data in tandem with billing records to help lay out the total system water losses. Second, the audit should report utility management practices in order to determine the location of these water losses. For further reference on water losses, The American Water Works Association released a manual entitled "Water Audits and Leak Detection M36".

Water audits can assist utilities in understanding the ways in which individuals use water. In Arizona, many utilities offer auditing services to their respective users allowing consumers to understand water usage tendencies and to find inefficiencies. Additionally, leak detection programs can also be used to locate inefficiencies in the water system.

Once leaks are detected, pressure reduction has been used as a method of managing water leaks. Higher pressure pipes have a higher tendency of bursting. Therefore, if flow-sensitive pressure control valves are placed this can reduce the excess flow of water. As a result, frequent changes in pressure can be minimized and extend the life of the water pipes. Pressure management may also assist in reducing the system energy requirements depending on the method of pressure reduction. If water pumps utilize pressure-reducing valves, then there will be no energy savings. Whereas, if pumps are operated by variable frequency drives, there can be some energy savings.

DEMAND-SIDE RECOMMENDATIONS

STRATEGY ASSESSMENT CRITERIA

Our analysis of water management strategies involves a hybrid of informed qualitative information gathered from primary and secondary research and available quantitative data, from current water demand statistics to case study benchmarks. It is our hope that current and future decision-makers view not only the strategies detailed on the following pages but also future UPC strategies through this analytic lens.

Our criteria consist of a set of qualitative guidelines and three comparison charts, each focusing on aspects of time, society, and government. The guidelines are not comprehensive, but are a starting point for shaping appropriate policies and strategies. For the comparison charts, the icon's relative size indicates the potential impact upon water conservation: the larger the circle, the greater the impact on water conservation. Included with each chart and criteria are leading questions, which can help initiate critical discussion on each policy and allow early stakeholder engagement.

Though the qualitative guidelines are not explicitly used as structural waypoints in the recommendations, they are implicit and have been listed here to help direct future analysis. In addition to implicitly using the criteria to develop the policy recommendations we put forth and quantitatively plotting each individual strategy, we hope that future strategies can also be evaluated and contrasted for effectiveness, efficiency, and feasibility.

QUALITATIVE GUIDELINES

CATEGORIES	LEADING QUESTIONS
Social implications: describes the social impacts and considerations of such a policy.	• What is the potential impact of the policy on the people of the Emirate? • Is there a specific segment of the population that will be more adversely affected than other?
Environmental considerations: describes the direct environmental impacts of the policy, both positive and negative.	• What are the direct environmental impacts of the strategy? Are there indirect impacts, whether positive or negative? • Are the environmental impacts widely known and understood?
Performance metrics: outlines metrics to gauge the success of the policy, its implementation, and its achievement of the intended outcome. Determining proxies for measuring success is useful if original metrics are challenging or cost-prohibitive to measure.	• What are the measurements by which the decision makers and implementers of the policy will need to measure success? What is another indicator of success? • What other factors could contribute to observed changes in that metric?
Challenges to implementation: describes the major obstacles that could prevent implementing the policy.	• What are the major obstacles in the way of implementing this policy? How are these challenges unique to this policy? • Are there lessons to be learned from implementing other policies?
Responsible stakeholders: identifies the stakeholders responsible for implementing the policy.	• Who are the stakeholders responsible for implementing the policy? • Do they fall within any public or private organizations, socio-economic groups, or sectors?
Affected stakeholders: identifies the stakeholders that will be affected by the policy.	• Who are the stakeholders that will be affected by the policy? • Do they fall within any public or private organizations, socio-economic groups, or sectors?

STRATEGY COMPARISON CHARTS

TIMING OF IMPACT

This chart shows the approximate time until the strategy can be put into practice versus the time until the results of the policy will be fully realized.

Strategies on the right of the chart take a longer time to put into practice than those on the left, and the results of the policies are realized sooner near the bottom of the chart than near the top.

Metrics:

X: Implementation spectrum from short to long-term (in years).

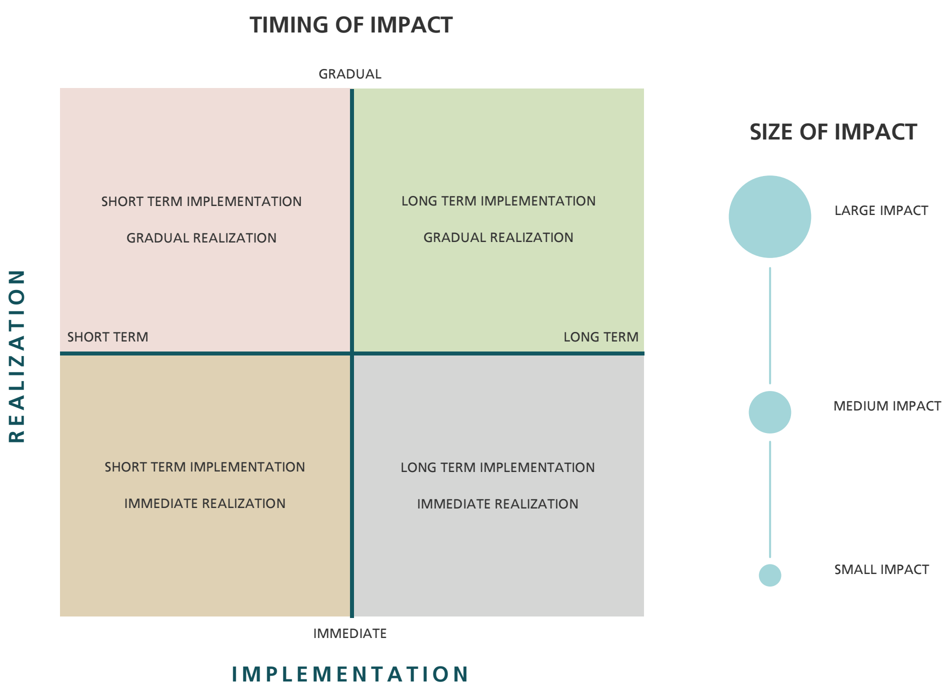
Y: Realization spectrum from immediate to gradual (in years); a relative scale from instant response to incremental approach.

Leading questions:

- When will the policy go into effect?
- How long until implementation and enforcement?
- How soon will the policy affect water demand?
- How large is the potential impact on water demand?

Example:

A pricing structure would go into place immediately, but it may take time for the policy to decrease the amount of water demanded (Policy – immediate (months), Result – gradual (3-5 years).



STAKEHOLDER INVOLVEMENT & SIZE OF ACTION

This chart shows the number of parties required to act (e.g., people, agencies, firms) and whether their burden is considered small or large in an attempt to ascertain whether a few are being asked to do a lot or whether a lot are being asked to do a little.

Strategies on the right of the chart require more parties to act than those on the left, and the burden they are being asked to carry ranges from nominal on the bottom half of the chart to very significant in the upper half.

Metrics:

X: Stakeholder spectrum as an estimate of number of parties (in number of agencies or individuals).

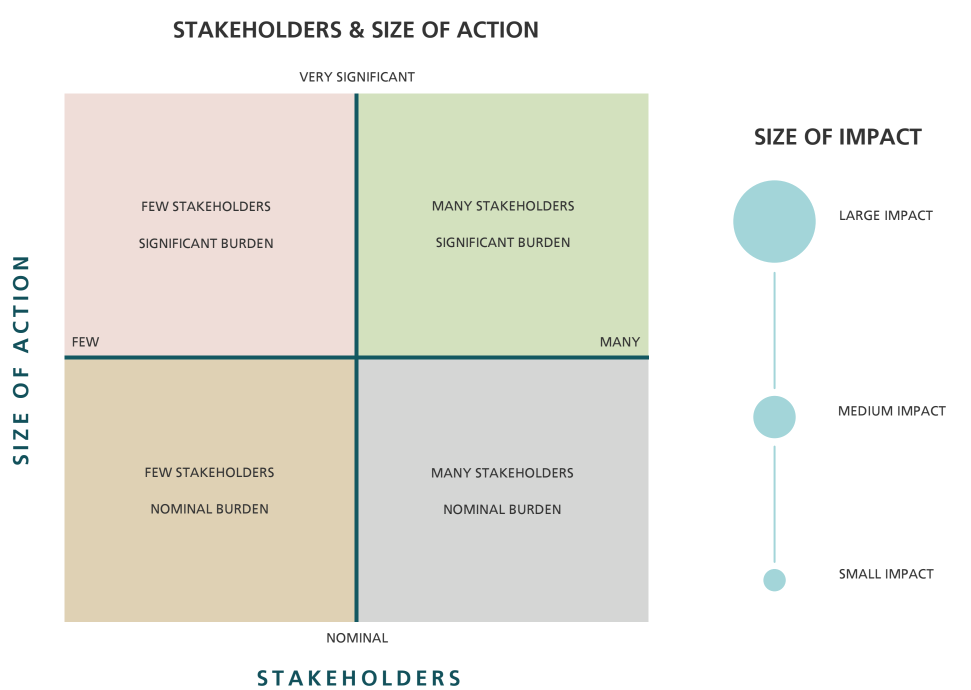
Y: Action spectrum as relative size of action required (from nominal cost or effort to significant cost or effort).

Leading questions:

- How many parties are being asked to act?
- How large or extreme is the action they are being asked to undertake?
- How large is the potential impact on water demand?

Example:

Is every homeowner being asked to make a small change (Stakeholders – many, Action – small) or is the policy directed at large-scale developers (Parties – few, Action – large)?



COST TO GOVERNMENT & CERTAINTY OF SUCCESS

This chart shows an estimate of the anticipated cost to the government for implementing the policy versus the estimated certainty of success and political feasibility of the policy relative to other policies.

Strategies on the right cost more than those on the left, and the degree of certainty of their success is higher on the top of the chart than on the bottom.

Metrics:

X: Cost to Government as an estimate of implementation costs (in Dirhams)

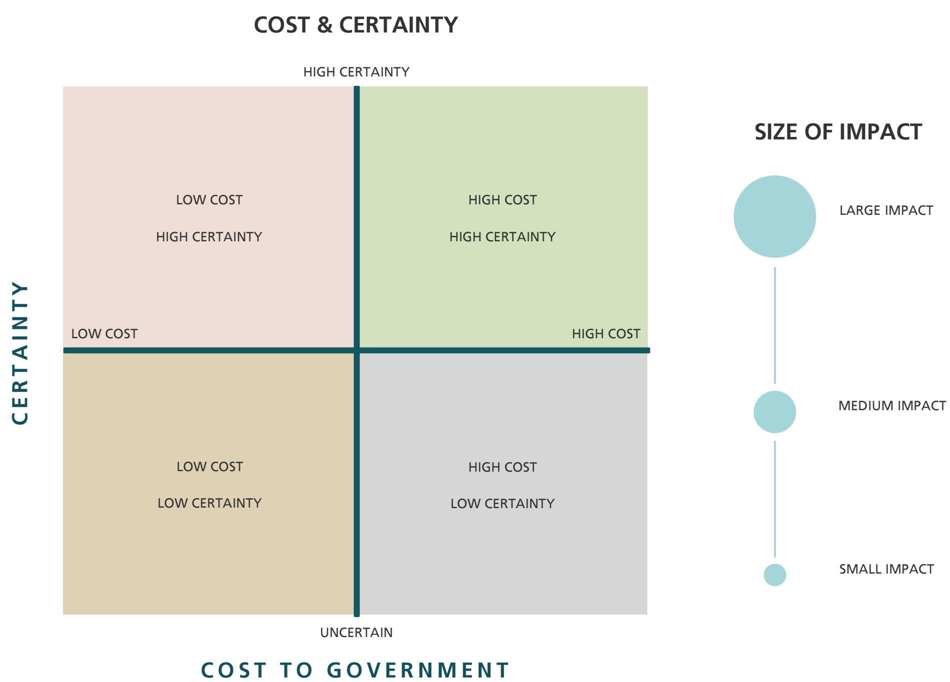
Y: Degree of Certainty as an estimate of certainty of success and policy feasibility (relative to other policies)

Leading questions:

- How much will this cost the government to implement?
- How easily will the policy be enforced?
- How certain are the results?

Example:

Would the policy require time-consuming inspections of every housing unit to check for efficient fixtures (Cost – high, Certainty – high) or would it rely on self-reporting (Cost – low, Certainty – low)?



POLICY RECOMMENDATIONS

This section outlines the key recommendations for sustainable management of Abu Dhabi's water resources. The recommendations consider four sectors where water consumption is high and where we believe there is potential for short- and long-term strategies:

1. The residential sector
2. The public realm
3. The agriculture industry
4. The tourism industry

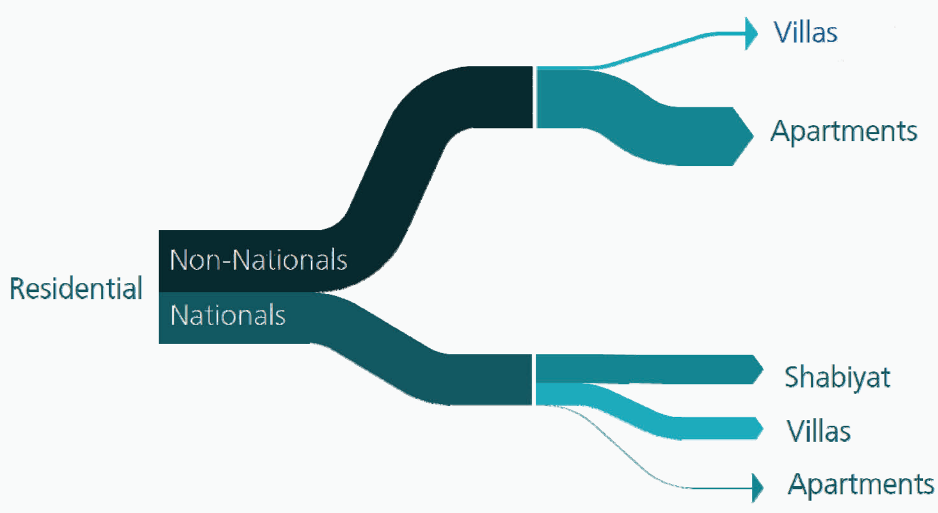
The set of recommendations has been evaluated using a framework that estimates the: (1) socio-economic and political considerations for the Emirate; (2) feasibility from political, technological and/or economic perspective; and, (3) the intention to create sets of best practices for modeling to other areas where water management is both achievable and desired. Additionally, we offer examples of what other communities and nations have done or are doing to achieve more effective water management and conservation on the pathway to water sustainability.

RESIDENTIAL SECTOR

Recommendations in this sector focus on one overarching goal: influencing Abu Dhabi's residents toward behaviors of water conservation. Our recommendations suggest a multi-tiered approach, with public education at the focus, based on two key reminders and "nudges"[78] of: (1) why conservation is important, and (2) the steps individuals within households can actually take to conserve water.

The residential sector represents a tremendous opportunity to increase water conservation across the Emirate. We propose three overlapping general strategic recommendations, and specific strategies within each recommendation, to increase residential water conservation:

1. Raise public awareness
2. Create a set of incentives to increase residential water conservation
3. Increase the value of water



The residential sector can be broken down into two main subgroups of residents: nationals (20% of total population), and non-nationals (80% of total population). It is evident on this schematic that even though nationals make-up only a small percent of the population, they consume almost equal amounts of water: nationals, 74.2 Mcm per year; non-nationals, 90.4 Mcm per year. Roughly 41.7 Mcm per year and 32.2 Mcm per year of national consumption can be attributed to high water use in shabiyat and villas. These forms of residence offer great opportunities for conservation in the residential sector.

(Water Resources Master Plan, 2009; Regulation & Supervision Bureau, 2009)

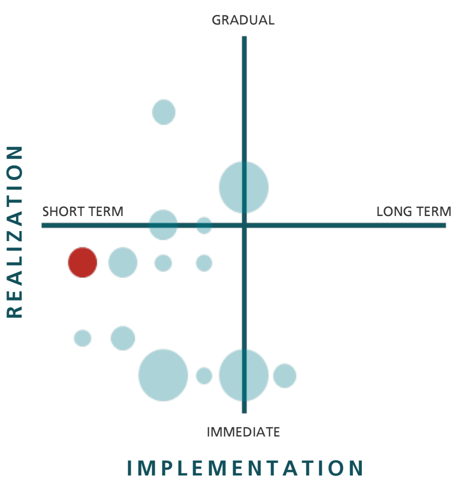
RECOMMENDATION 1: RAISE PUBLIC AWARENESS

To reduce water consumption and to achieve the goal of sustainable water management in Abu Dhabi, the government must first increase awareness about water conservation among its residents. All of the strategies rely upon the Emirate's residents having a clear understanding of both water scarcity and the concrete steps they can take to reduce their consumption. Awareness campaigns that are holistic and cogent have a higher probability of being effective in terms of overall awareness and action.

Recent government measures in the UAE to improve public awareness, such as the creation of the *Heroes of the UAE* campaign[79], signal a willingness to work for greater awareness on sustainable use of water and energy. In energy conservation, for example, promoting awareness so that people believe in a possible shortage of energy in the future and an understanding that their lifestyle is contributing to the shortage has led to substantial conservation results.[80] As seen with energy use, basic awareness is fundamental when attempting to shift the behavior of people toward conservation. We outline two strategies for increasing public awareness on water scarcity and conservation within the Emirate: first, launching a mass media water conservation campaign, and second, using influential public figures to propagate the message of water conservation.

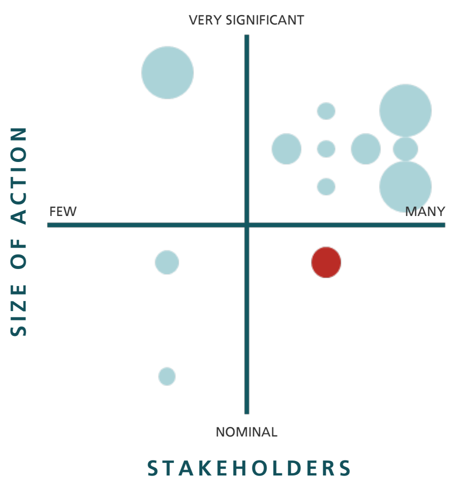
STRATEGY 1.1: LAUNCH A MASS MEDIA CAMPAIGN

TIMING OF IMPACT



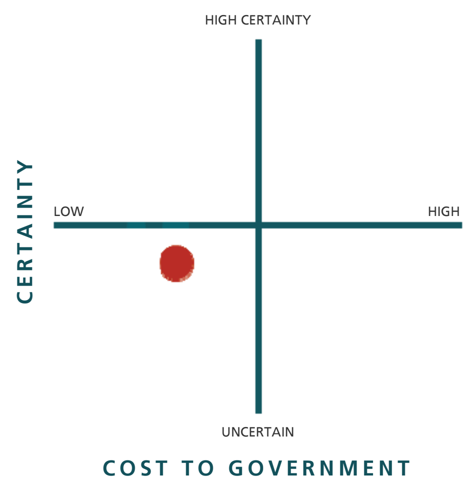
Implementation: 0-1 years
Realization: 3-5 years
Size of Impact: 5-10 Mcm

STAKEHOLDERS & SIZE OF ACTION



Stakeholders: 2-3 agencies (EAD, EAA, RSB)
Size of Action: Modest
Size of Impact: 5-10 Mcm

COST & CERTAINTY



Cost to Government: 10-25 million Dh
Certainty: Somewhat uncertain
Size of Impact: 5-10 Mcm

We suggest that the UPC launch an Estidama-led mass media campaign to increase public awareness on the issue of water and energy sustainability in the Emirate. Mass campaigns are traditionally used to raise interest on an issue and disseminate information that can be applied to many individuals.[81] Mass media campaigns are an immediate, direct, and efficient way of reaching a large target audience and messages spread through the media have the ability to influence human behavior.[82] In the United States, mass media campaigns have successfully influenced public knowledge and behavior on issues such as drug abuse, cigarette smoking, traffic safety, and the environmental effects of pesticides.[83] The UPC's active involvement and use of the media can lead to an increase in awareness of water and energy conservation measures and can positively impact peoples' attitudes and behaviors toward achieving sustainable energy and water management.

In order to use a mass media campaign to increase public awareness on more effective water management and conservation, Estidama and the UPC may consider developing the following three instruments:

1. **A message:** a clear, concise, compelling, and accessible message for the public.
2. **A messenger:** a person, character, or mascot who delivers the message with the aim of becoming synonymous with it, as in many other successful media campaigns.
3. **An outreach plan:** a strategy for employing various methods of communication to carry the message to the public.

Working with a hired marketing firm or professional, the following are the recommended details on how the UPC and Estidama can create and deliver their water management campaign in a way that draws public attention to the subject matter and increases participation in the overall goal increasing water conservation.

THE MESSAGE

For a mass media campaign to be effective, it must deliver a clear and easily understood message: what the issue is and what needs to be done. An analysis of similar campaigns undertaken elsewhere reveals that one of the most crucial factors in dictating a water conservation campaign's success is the articulation of a clear per capita consumption target. Through our primary research we have identified a possible goal of 250 liters per capita per day, a drop of 200 liters per capita daily from current average consumption. This level of consumption would place Abu Dhabi closer to the levels of consumption of countries with similar hydrological resources. We realize that change in consumption will take time and effort on the part of residents and others engaged in education efforts. In articulating an actual numeric goal, we intend to identify a target around which public awareness and outreach campaigns can focus their message and guide consumers to behaviors that conserve water. Whether or not this actual numeric goal is appropriate for such an educational campaign rests with the implementers within Abu Dhabi.

To increase water conservation, a suite of strategies must be employed, working in concert toward a highly publicized, set goal of per capita water consumption reduction. In Queensland, Australia, which has suffered significant droughts over the past few decades, the policy target has become a marketing campaign. "Target 140,"[84] as the program was called, was a tremendous success:

> *[the] radio was awash with talk of water and how to conserve it. Reservoir levels became the subject of everyday conversation. Just two weeks into Target 140, average daily per-person use dropped from 80 to 32 gallons. The water saved was equivalent to bringing a desalination plant online—overnight.*

What is notable about the success of the campaign is that the behavioral inducements at play in Australia were linked to clear goals and worked because of a strategy mix of new regulations and more subtle nudges. This “systems-based approach” to behavior changes at the micro level is most effective when it is pursued at the macro level as well—in business, industry, and government.

We suggest that the message be clear and that it invites participation from those who view it toward the positive benefits of reducing consumption for the individual and for the country. One example of where successful water reduction has taken place is Jordan, where Water Efficiency and Public Information for Action (WEPIA) sent the message of simple, cost-effective actions individuals could take.[86]

THE MESSENGER

The messenger of the campaign is often a recognizable character, figure, or mascot with whom the people living in Abu Dhabi can identify and build a trusting relationship. We recommend that the character share similar characteristics and qualities with its audience—allowing the audience to better relate. For example, Jordan’s Abu Tawfir is relatable to Jordanians because he shares a similar family composition, personality, and occupation which are representative of a many Jordanians.

Examples of successful use of characters to persuade audiences to take action are Abu Tawfir, Rowyan, and Birdie:

ABU TAWFIR

Creator: Water Efficiency and Public Information for Action (WEPIA)

Character Details: Abu Tawfir, which means “papa miser” in Arabic, portrayed the typical average Jordanian as a government employee living in an urban setting with his wife and son.

Location: Jordan

Purpose: Used for a water shortage educational campaign in an effort to show that reducing consumption does not have to cost a lot of money.

Message: *“The solution starts with you.”*

Success:

- 82.9% increase in public awareness of the water shortage problem in Jordan.
- 30% increase was seen in the number of Jordanians who linked population growth to the problem.
- 9.3% increase achieved in those attributing the water shortage problem to limited water resources.[89]

ROWYAN & ROWYANA[90]

Creator:	Yemen's National Water Resource Authority and German based company GTZ's Integrated Water Resources Management Project
Character Details:	Rowyan is an animated raindrop character with moustache and headdress. His wife, Rowyana, which means "I've had enough water" in Arabic, wears a veil and full-length black robe, carries a handbag, and has long eyelashes.
Location:	Yemen
Purpose:	National mascot developed to encourage water conservation
Message:	To make more efficient use of every drop.
Success:	• There is a high demand for Rowyan products. • The Yemen Polling Center Hafez Bukari believes Rowyan could have a powerful impact if all the relevant government ministries and international donors support the initiative.

BIRDIE[91]

Creator:	GreeNYC – Mayor's Office of Long Term Planning and Sustainability
Character Details:	A cute green bird.
Location:	New York City, USA
Purpose:	Demonstrate ways that New Yorkers can help make New York more energy efficient and "green" as part of the environmental consumer-education campaign.
Message:	*"Small Steps, Big Strides."*
Success:	• For the anti-idling campaign: public service announcements and public relations initiative for the campaign generated over 194.6 million total media impressions among drivers in New York City. • 111% increase in number of idling related, same-month calls over the period of the year during the campaign dispersion.[92]

When used effectively, a character has the potential to become a part of the culture and recognized by people of all ages. From coloring books to fact-laden websites, the messenger and its message can become a part of early education via school curricula and later-generation learning through targeted public announcements. Thus, we suggest that the messenger is created with younger and older generations in mind.

METHODS OF COMMUNICATION

Once the message and messenger have been established, Estidama and the UPC can then select an effective means of communication to their audience through use of both traditional and new forms of mass media.

Traditional forms of mass media include signs/billboards, print newspapers and magazines, print literature and advertisements, and Public Service Announcements (PSAs) on both radio and television. The *Heroes of the UAE* campaign is currently using billboards to promote awareness of their campaign and its messages. We suggest that campaign organizers use a strategic mix of traditional mass media to raise awareness of and increase participation in water conservation.

Through the Ministry of Information and Culture, the UAE encourages freedom of the press, constrained only by precautions that protect the country's and its people's religious and political integrity.[93] The UAE has six satellite and several non-satellite TV stations. It also has more than 7 radio stations, 5 Arabic and 3 English daily newspapers, and more than 160 magazines and journals in circulation published by local and national entities.[94] Newspapers are read by over 70% of the population in the UAE, while television reaches 86% of the population.[95] We encourage Estidama to take advantage of these resources and to work with the appropriate agencies to secure broad dissemination of their message. The advantage to using UAE-wide services like television and radio stations is that eventually Estidama can release their campaign beyond the Emirate of Abu Dhabi to the whole country.

In addition to traditional avenues of communication, new media is encouraging increasing unity in the Middle East and celebrating the cultural diversity of the region by helping to highlight and mobilize public opinion and by allowing citizens to become more informed and to participate on issues of common concern.[96] New media includes technologies such as the Internet and mobile phone connections. The Internet acts as a means of global communication that is open to the public and it has enabled government agencies and organizations to easily publish, disseminate, and store information. Moreover, the ease of Internet use has allowed government entities to reach more people and has facilitated public participation, information sharing, transparency, and conversation. According to Emirates Media, Inc., as of September 2009 there were 2,922,000 Internet users accounting for 60.9% of the population in the UAE[97] and leading Internet usage rates among all countries in the Middle East. While the UAE is impressive in its effort to use the Internet for public relations, many of its outputs only offer one-way communication (from the source to the user).[98] To encourage more participation, we suggest that Estidama's Internet-based campaign ensure that communication has the ability to flow in both directions and to adapt to user feedback.

Similar to Internet usage, mobile services in the UAE are also increasing despite there being only two mobile services providers in the UAE, Etisalat and Du. Both the CIA World Factbook and UAE Yearbook 2009 report that mobile penetration in the UAE is over 200%. As of 2008, the total number of mobile cellular subscribers in the UAE was 9.4 million and is expected to grow to 11.9 million by 2010.[99] Of the total subscribers, 3G subscribers account for 28%, a number that is also increasing.[100]

Number of Internet Users (2000)	Number of Internet Users (2004)	Number of Internet Users (2009)	Percent of Population (2004)	Percent of Population (2009)	User Increase between 2000-2004	User Increase between 2000-2009
735,000	1,110,200	2,922,000	44.0	60.9	51%	297%

Table 5. Various internet user statistics of the Middle East. (Internet World Stats (http://www.internetworldstats.com), Nua Internet Surveys (http://www.nua.com/surveys/how_many_online/m_east.html), International Telecommunication Union (http://www.itu.int/ITU-D/ict/statistics/at_glance/Internet03.pdf)).

We believe that Estidama can increase awareness and launch a successful campaign by taking advantage of these growing media. Some examples of how they can do so are:

- **"Web 2.0"**: Estidama can take advantage of its existing website, (www.estidama.org), include specific information about the campaign, and make the website even more interactive. The website could include a variety of tools to engage the user: a water consumption calculator, which would give average consumption numbers for the user's identified use; conservation tips; frequently asked questions about conservation; a discussion forum; photos; and, a blog that follows the campaign's efforts and allows immediate response and interaction between Estidama and the people of Abu Dhabi.
- **Social Networking Sites** (e.g. Facebook,[101] YouTube, Orkut, MySpace, Twitter): The campaign can use social networking sites to attract people to the campaign, keep committed supporters motivated, and provide current information to all of its supporters.
- **Applications**: Water-based conservation applications for smart mobile phones (Apps) can be designed for anyone with an appropriate device. These could include a how-to-save water/energy application, applications based on campaign events, and a water consumption calculator.
- **Miscellaneous multimedia**: Advertisements and interesting water facts can be shown in elevators, on airplanes, and other creative places.

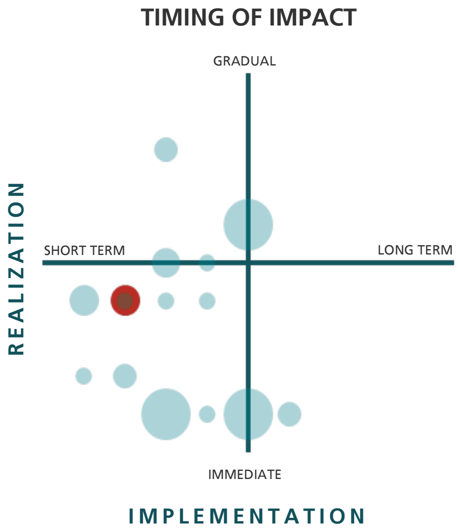
Understanding the Effectiveness of Public Awareness Campaigns

In order to understand the impact of the public awareness campaign, Estidama can make use of surveys and assessments to confirm whether the print, broadcast, and new media campaigns are achieving anticipated results. Studies can be conducted during Year 3 and Year 5 of the campaign (see sample study below). The goal of such an assessment would be to determine whether campaigns are impacting the public through a visible increase in both public awareness of and action taken toward water conservation. If successful, the campaign will create a behavioral change in the people living in Abu Dhabi and a significant decline in water consumption. To test this further, post-campaign research, including the use of surveys and interviews, can be conducted to get sample responses to the campaign. After the rollout of the Abu Tawfir campaign in Jordan, interviews of 400 people proved the campaign to be an overall success with more than 80% of interviewees recalling seeing the television spots and being influenced to change their behavior. Likewise, 57% of interviewees recalled seeing a print ad with Abu Miser in the month prior to the survey.[102]

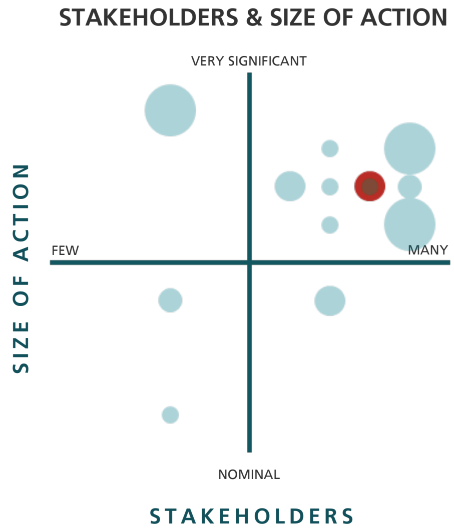
Sample study:
To assess whether a large target group audience is reached, Estidama can use some of the following criteria:

1. Make certain that people have access to the campaign. This can be done by setting target goals for different means of communications and then identifying whether or not the goal was met:
    - What percentage of the target group read a regional newspaper or signed up to join the campaign online? How many people heard the advertisement on the radio, saw it on television, or drove past the billboards?
2. Identify the perception of the campaign and whether the intended purpose was satisfied:
    - What percentage of people who perceived the campaign lived in a specific region compared to the whole Emirate?
3. Determine whether the purpose of campaign materials was fulfilled:
    - What percentage of people who saw the advertisements and editorials read them? What percentage of people came saw a PSA and watched it in entirety?
3. Capture the attention of the mass media to cover specific campaign events:
    - How many press people attended and report on major campaign events?

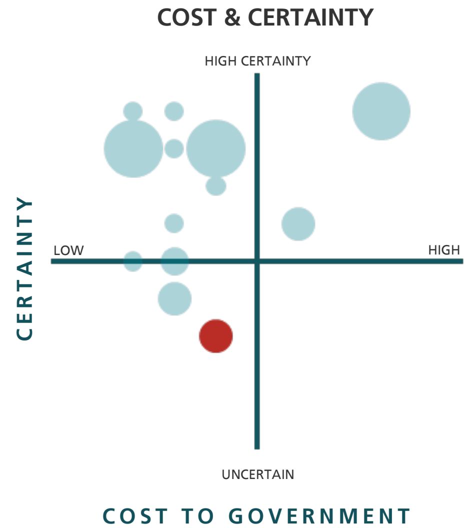
STRATEGY 1.2: USE PUBLIC FIGURES TO PROMOTE WATER CONSERVATION



Implementation: 1-2 years
Realization: 3-5 years
Size of Impact: 5-10 Mcm



Stakeholders: The majority of public figures and religious leaders (appx. 3,000)
Size of Action: Significant
Size of Impact: 5-10 Mcm



Cost to Government: 1-10 million Dh
Certainty: Somewhat uncertain
Size of Impact: 5-10 Mcm

Using influential public figures, including political leaders and religious figureheads, is one of many potential ways to effectuate behavioral change in Abu Dhabi. Social psychology literature over the last twenty years indicates that the influence of public figures plays a major role on an individual's ability to make a decision to act and determines how the individual responds to the outcomes of such decisions.[103] Public figures' influence on shaping a new social water consumption norm could play a significant role in Abu Dhabi, especially if public figures make individual commitments to increase their water conservation.

How to best incorporate such public figures depends on the public figure, the targeted audience, and how he or she can best be used to bring attention to the desired behavioral shift (i.e., toward sustainable water use and conservation). For successful use of public figures with water conservation campaigns, agencies like the UPC and EAD may want to identify the appropriate public figure(s) to help launch their platforms and participate in various campaigns, such as the *Heroes of the UAE*. We recommend that the agencies choose charismatic and admired individuals who will be hired for specific roles, like Ambassador on Sustainable Water Management, for a certain time period.

Political and religious leaders may be appropriate candidates to promote behavioral changes and to make public conservation commitments, thus shaping a more sustainable social norm.

POLITICAL LEADERS

In the political and social context of UAE, a strong public awareness campaign might have initial endorsement and then be reinforced throughout the span of the campaign by credible political leaders who publicly commit to the goal of sustainable water management and support efforts which work toward achieving it.

We encourage the UPC to involve of members of the royal family, if possible, such as HH General Sheikh Mohammed bin Zayed bin Sultan Al Nahyan, Crown Prince of Abu Dhabi. The Crown Prince is an example of a political representative who may be beneficial in a public awareness campaign because he is recognizable and respected by the people of Abu Dhabi. In addition to these important qualities, the Crown Prince also has an immediate connection to environmental issues and is currently an honorary chairman of the Environment Agency of Abu Dhabi (EAD). Support from a political figurehead like the Crown Prince can generate public interest in water-related issues, such as the recycling of greywater in agriculture enterprises, and more importantly aid in educating and influencing the public on the corresponding issues like the use of greywater.

Other potential people of influence include local community leaders and municipal authorities who are popular and have the ability to lead their constituents in committing to the goal of sustainable water management. While local community leaders may represent smaller geographic areas, they still have high levels of influence; often, the smaller the region of influence, the bigger the interaction and connection between the individual and the people. Proximity is therefore critical to connect and influence the public on water conservation, and using those political leaders to lead an organized effort can also be valuable.[104]

RELIGIOUS LEADERS

The UAE is 96% Muslim, accounting for approximately 1.68 million of the country's people,[105] providing a large audience through which to raise awareness of water as a critical issue within Abu Dhabi. Islamic teachings, in the Quran and the Sunna, have a large influence on everyday life in Muslim society and teach the importance of conservation of natural resources, especially water.[106] Using Islamic principles on water conservation in campaigns may allow the campaign to reach a greater portion of society with strong appeal and at relatively low implementation costs.

Religious leaders, such as imams in mosques, have the ability to influence and reach out to a large congregation of people. In a field survey in Amman, Jordan, 63.5% believed that the imam of a mosque should have an important role in environmental education and public awareness.[107] We recommend that the UPC help create literature and training materials to inform imams on the importance of water conservation so that they may raise awareness among their congregants. Imams can incorporate behavioral changes at the mosques specifically by:

- Teaching congregants to use less water during ablution[108] to create a positive change in the pattern of water consumption use, and
- Modeling the proper use of water meters in washrooms to quantify water consumption and create feedback that directs awareness of the impact small behavioral changes can have on overall water use.

We encourage the UPC to coordinate with the General Authority for Islamic Affairs and Endowments and agencies such as the EAD and the Regulation & Supervision Bureau (RSB) to implement the proposed strategy. The General Authority for Islamic Affairs and Endowments is already working with religious figures of mosques in Abu Dhabi to promote sustainable education campaigns as part of their permitting process with Islamic temples and authorities. Continuing and expanding on this effort to work with imams may be the most effective way to spread the water conservation message in mosques.

RECOMMENDATION 2: INCREASE WATER CONSERVATION INCENTIVES

Dovetailing with the mass media campaign, the second strategic focus of the effort to reduce residential water consumption is to increase water conservation behavior through a suite of incentives. One of the great interdisciplinary successes of the last century was combining the fields of psychology and economics, pulling the insights from both disciplines, and developing important new insights that were missed by each alone. This new field is behavioral economics and it has a tremendous amount to offer to decision makers who aim to craft policies that are sound, effective, and efficient. Such gains in policy efficiency, above all else, are a product of strategies that are non-coercive and do not require unwieldy and costly enforcement mechanisms. Changing the behavior of a citizenry can be expensive in real and political and social capital, but the discourse on behavioral economics points to an innovative toolset, which can induce desired behavior changes with minor or even unnoticeable shifts in policy. When combined with other strategies, such inducements can achieve many of the desired gains of more sweeping and costly policies. This section links these innovative behavioral inducements to the policy problem of potable water overconsumption in the households of the Emirate.

The real insight of behavioral economics is that minor changes in behavior can help realize tremendous gains. For example, if everyone in the Emirate used 50 fewer liters of water daily (a mere 9% reduction), aggregate consumption would drop by over 18 million cubic meters per year, the rough equivalent of water produced by over 40 days of continuous operation by Umm Al Nar desalination plant. Modest changes like this, in concert with incentives to use high efficiency fixtures, can quickly add up to tremendous water conservation. Further, a new behavioral disposition can help create the ethos around conservation that can foster sustainable consumptive behavior in the Emirate's future generations. The question for the behavioral economist is how best to induce such changes in the population at lowest cost to policy.

Recent studies from the Center for Research on Environmental Decisions have confirmed that when people are asked for the most effective way they have to save water or energy most participants mention curtailment (turning off tap water or lights) rather than efficiency improvements. Many people still have considerable misconceptions about the effectiveness of their actions, and according to scholars, such perception, if changed at a household level, can lead to consumption reductions of nearly 30%.[109]

The Incentive of Pricing

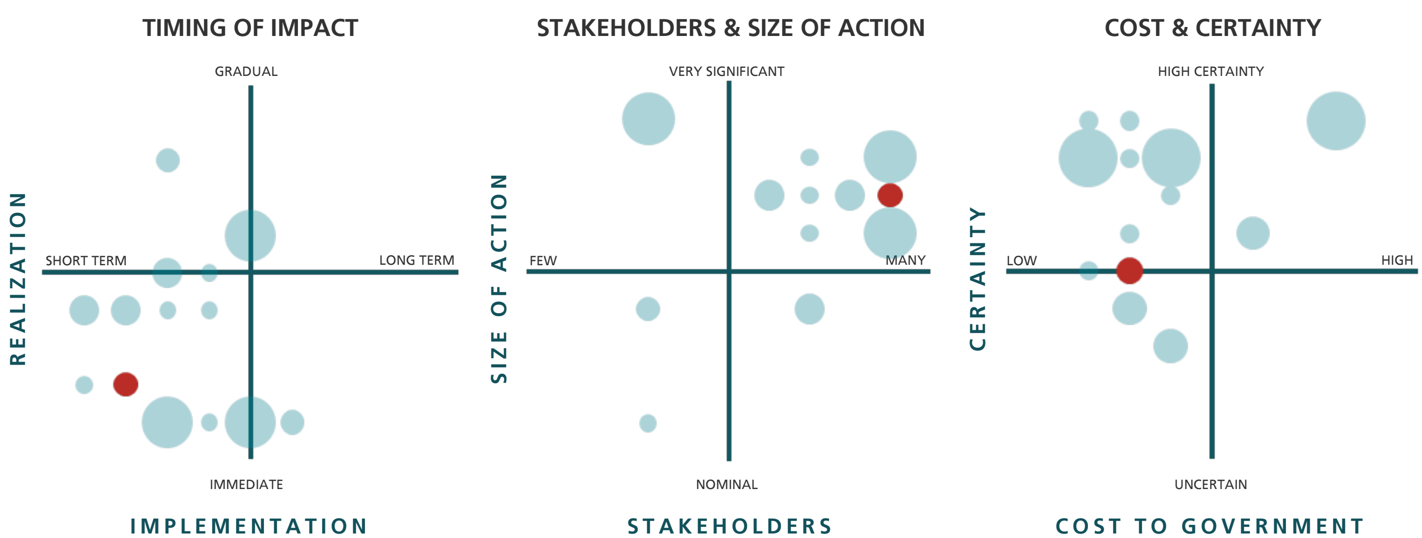
A 2001 study examined the effects of a new water-pricing scheme in Abu Dhabi City. Prior to the new scheme, a flat fee of 50 Dh was charged to consumers irrespective of the amount of water consumed. In January 1997, the Water and Electricity Department (WED) of Abu Dhabi, the agency responsible for water supply and production, decided to replace the flat fee program with a scheme that charged consumers a price based on the amount of water used at a rate of 2.2 Dh per cubic meter. The authors converted the flat fee of 50 Dh to a cost per unit of water of 0.56 Dh per cubic meter based on an assumption of a family of 5 using 88.5 cubic meters per month, the new price of 2.2 Dh per cubic meter a 290% price increase. A sample of 90 users with different socio-economic status was examined; the results that 73% of users reduced their water consumption an average of approximately 29%.

(Abu Qdais, H.A. and H.I. Al Nassay. "Effect of pricing policy on water conservation: a case study." *Water Policy* 3 (2001) 207–214.)

Studies have shown that using encouragement and providing feedback on an individual's actions can induce larger changes than by giving them non-specific information alone. We recommend that Abu Dhabi consider providing individuals with accurate information about their individual water consumption and its implications on water in Abu Dhabi in order to shift perceptions of effective water use and to promote individual changes that make a bigger difference.[111]

The Economic Affairs Unit of the Executive Affairs Authority (EAA) is currently developing programs in conjunction with various agencies to encourage consumers to reduce waste of water.[112] On the water pricing side, a progressive increase to water tariffs has been suggested, however it should be noted that the UAE has preempted plans to study tariff increases.[113]

STRATEGY 2.1: PROMOTE CLEAR REDUCTION STRATEGIES



Implementation: 1-2 years
Realization: 3-5 years
Size of Impact: 50-70 Mcm

Stakeholders: All residents in Abu Dhabi
Size of Action: Significant
Size of Impact: 50-70 Mcm

Cost to Government: 10-25 million Dh
Certainty: Average uncertainty
Size of Impact: 50-70 Mcm

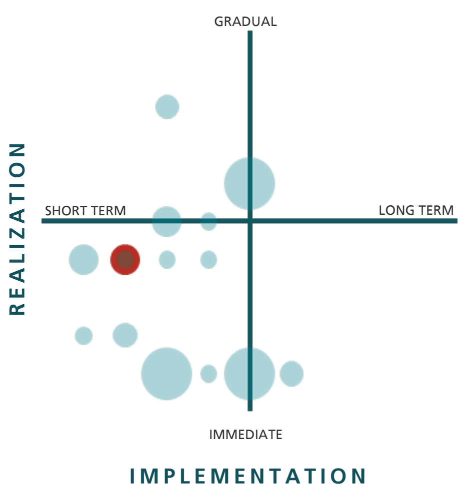
The recommendation to raise public awareness through a media campaign has important interplay with changing consumptive behavior. Coupled with the message of a clear reduction target we recommend that Abu Dhabi create clear directions on what individuals can do to increase water conservation. Incentives, such as rebates on pool covers, low flow showerheads, dual-flush toilets, water efficient appliances such as dishwashers and laundry machines can ensure that many are installed in households, particularly villas, over a short period. Residents can also perform important checks on the water distribution network, checking sinks, faucets and piping both in and out of doors for leaks, so long as they are educated on what to do if leaks are present. Linked to such a strategy could be subsidies for plumbing costs and changes, providing an important mechanism for ensuring that the distribution network is as efficient and leak-free as possible.

Perhaps two of the more important household changes that can be made under the guidance of such a campaign could include villa gardening and private car washing. The timing of villa garden watering and the composition of the villa gardens themselves are important factors in determining household consumption. Xeriscape gardening,[114] a type of gardening developed in many desert climates, focuses on appropriate plant choice and creating a landscape that can be "maintained with little supplemental watering."[115] Garden enthusiasts or local landscapers can be given incentives to encourage such gardening strategies. Further, changes in the timing of villa garden watering will be important. Encouraging watering by sprinklers and villa caretakers in the early morning and evening will ensure that less water evaporates than during daytime temperature peaks.

The aridity of desert climes means that dust is a continual presence, particularly on vehicles. The value placed on a clean cars is tremendous throughout the Middle East and the role of continuous, even daily car washing in driving up consumption levels can hardly be understated—some estimates place residential car washes as high as an astonishing 600 liters.[116] As the economy in Abu Dhabi continues to grow, vehicle ownership will also likely increase. Changing the social premium placed on clean vehicles is not something the Emirate can alter in the short, or perhaps even, long term. However, Abu Dhabi can nudge vehicle owners and their caretakers into washing vehicles at certified commercial carwashes that can be regulated to ensure maximum water conservation, such as water recycling. Further, commercial carwashes in the United States and elsewhere have gone waterless, using environmentally friendly sprays and special cloths to clean vehicles without water.[17] The status symbol of a clean car will not change, but the means of maintaining the symbol can be. Coupled with an awareness campaign and incentives to increase capacity and water conservation to commercial car washes, a social norm of washing vehicles only at carwashes can be engendered. For example, the government can incentivize Abu Dhabi-based car dealerships to sell cars with car washing packages included.

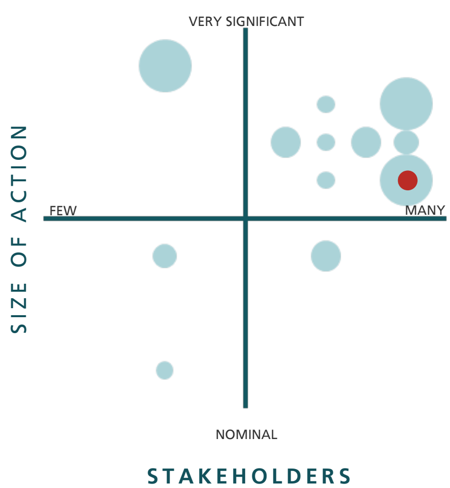
STRATEGY 2.2: GIVE CLEAR FEEDBACK

TIMING OF IMPACT



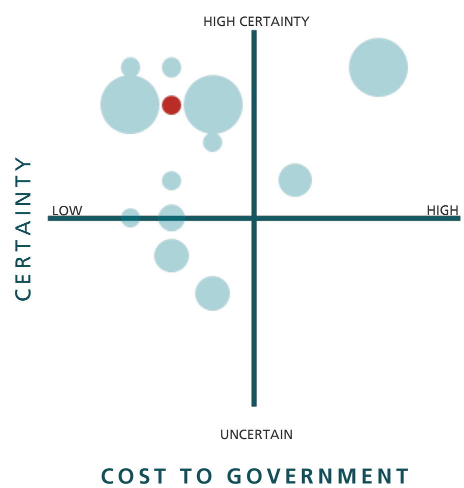
Implementation: 1-2 years
Realization: 3-5 years
Size of Impact: 20-30 Mcm

STAKEHOLDERS & SIZE OF ACTION



Stakeholders: All residents in Abu Dhabi
Size of Action: Modest
Size of Impact: 20-30 Mcm

COST & CERTAINTY



Cost to Government: 10-25 million Dh
Certainty: High certainty
Size of Impact: 20-30 Mcm

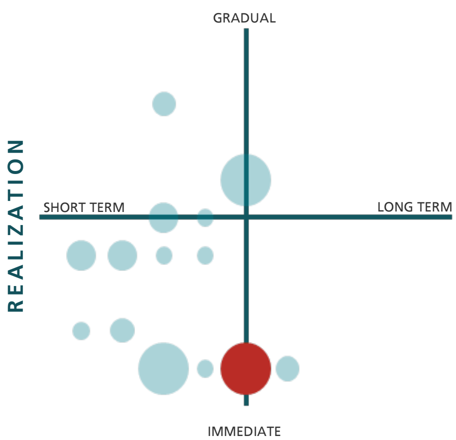
Feedback, particularly visual feedback, on individuals' water conservation performance is an important tool in changing ingrained consumptive patterns.[118] If households receive feedback on their water usage based on metering, there is an opportunity not just to educate, but also to create a sense of competition among households through recognition of good and bad behavior, creating a race to the bottom in water conservation.[119] This type of peer pressure is becoming an important strategy to breed competition among households. In the United States, the social phenomenon of keeping up with one's neighbors is being exploited to induce environmental and sustainability changes that otherwise are difficult to bring about. Waste is often a sign of wealth and success; the policy innovation has been to turn this on its head and to make conservation a sign of success, even for people who do not care about sustainability or the environment.

Metering private water can be a powerful tool to change citizens' consumptive patterns in Abu Dhabi, but a key in shifting behavior is first determining the impacts of behavioral changes.[120] As metering continues to expand in the Emirate, we encourage the government of Abu Dhabi to educate all residents on what the meters are and how they can be used to reduce their consumption. Agencies like the UPC or EAD can support the initiatives but may play more of an advisory role in sequencing the most effective messages. This behavioral modification has been employed to great effect in the electricity sector of the United States. To reduce household electricity consumption, some electric utility companies in California, Washington, and Illinois have given their consumers simple and effective visual feedback on their electricity use: "happy and sad" faces on their utility bills.[121] The single criterion for the different faces is their relative electricity consumption. Happy faces show that the household uses less than the average electricity consumption for neighboring households. Sad or unsmiling faces denote a consumption rate that is higher than one's neighbors. Coupled with simple bar charts referencing a household's historical consumption, this strategy can be employed under water metering as well as a set water reduction target to induce households to compete.

However, we strongly encourage, that before pursuing this strategy, the Emirate will likely need to have in place a comprehensive water monitoring and data management system. Moreover, we suggest a pilot program to ascertain the effectiveness of such an approach. Finally, for reasons of sequencing the right messages, agencies like the UPC or EAD could support the initiative but play more of an advisory role in sequencing the most effective messages.

STRATEGY 2.3: CHANGE THE VALUE OF WATER

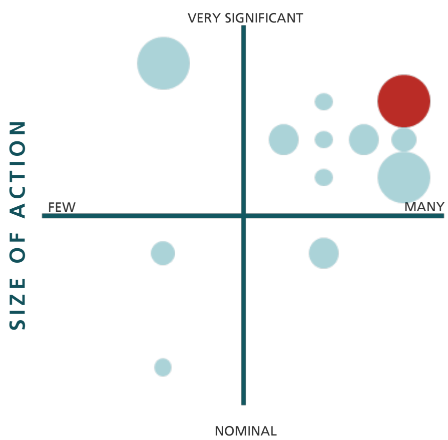
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 5-7 years
Realization: 0-1 years
Size of Impact: +100 Mcm

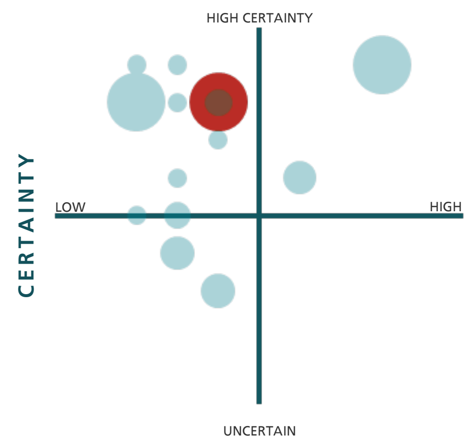
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: All residents in Abu Dhabi
Size of Action: Significant
Size of Impact: +100 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 25-50 million Dh
Certainty: High certainty
Size of Impact: +100 Mcm

Many countries in the Middle East subsidize water and have historical and cultural reasons to continue to provide this service to their people. However, campaigns for water demand reduction with the good—water—holding a market value is an important tool in achieving sustainable water practice. Throughout the Gulf, nations are examining strategies ranging from water tariffs, pricing water at cost, and conservation subsidies. International research has shown that households who receive water piped into their homes are willing to pay between three to five percent of their income to access clean water.[122] Pricing policies, water use restriction, and wastewater reuse can impact water used in commercial settings. In Jordan, a steel mill reduced its demand for water from 450 m^3 to 20 m^3 when cooling water was recycled.[123]

Residents of the Emirate of Sharjah have been encouraged to use less water as well as electricity. The Sharjah Electricity and Water Authority's director, Waleed Khalid Bin Khadem, said about a new pricing proposal, "The proposal of the new system will help rationalize consumption of electricity and water because consumers will be able to calculate the value of their electricity and water bill according to their consumption," which will help to reduce consumption and limited natural resources.[124] The Dubai Electricity and Water Authority (DEWA) has presented a new water pricing structure to bring down consumption of water. Residents pay 3 fils per gallon to a maximum withdrawal of approximately 27 m^3 (6,000 gallons) per month. If residents exceed 6,000 gallons, the price will increase to 3.5 fils (.009 cents).[125] For consumers who use more than 12,001 gallons, they will be charged 4 fils (.01 cents) per gallon.[126] Such rates are progressive and an important step, but the DEWA expects these price increases to affect only 20% of the population of Dubai as Emiratis are exempt from such tariffs.[127]

In other areas in the Middle East, governments are realizing that sustainable water policies need to take center stage. For example in Kuwait, the government has subsidized water since the 1960s. The government has realized that their current approach of increasing desalination outflows and increasing the amount withdrawal is not working; if it were to continue, the approach could lead the country into a water crisis.[128] Kuwait has used a flat rate subsidy and is looking to restructure its water tariffs to promote water savings. The government is considering replacing the flat rate subsidy with block rate pricing as well as increasing rates to encourage the population to use water more efficiently.[129] It was determined using modeling that charging US $1 per cubic meter (3.67 Dh) after 150 liters per capita per day allowance would decrease water consumption by 35%, which would yield net benefits of US $420 million per year (1.54 billion Dh).[130] The study noted that while government officials accepted the need to change the tariff system, it would be much more difficult to convince the public. In Kuwait, less than 25% of water charges are actually collected and attaining any significant improvements requires metering and bill collection to be enforced.[131]

Case literature on creating a price for water spans the gamut. Some literature notes that restricting water for urban use can best be accomplished through community policing and stiff fines.[132] According to the Organisation for Economic Co-operation and Development (OECD), countries are encouraging water conservation by switching from fixed charges for public water services to volumetric charging—the more you use, the more you pay. Volumetric charging decreases block tariffs, which reduces the practice of providing discounts to high-volume users.[133] For example, countries such as Hungary, Poland, and the Czech Republic are using volumetric pricing. While there still are countries using fixed charging, generally, the provision of free water is largely on the decline.[134] OECD believes that any scarce good in demand needs a price, and thus, water pricing is seen as a necessary instrument of public policy. We recommend that Abu Dhabi conduct a thorough study of all potential schemes that may help the Emirate's residents appreciated the value of water. This decision is best made by policy makers in the country who empathize with the sentiments of the Emirate.

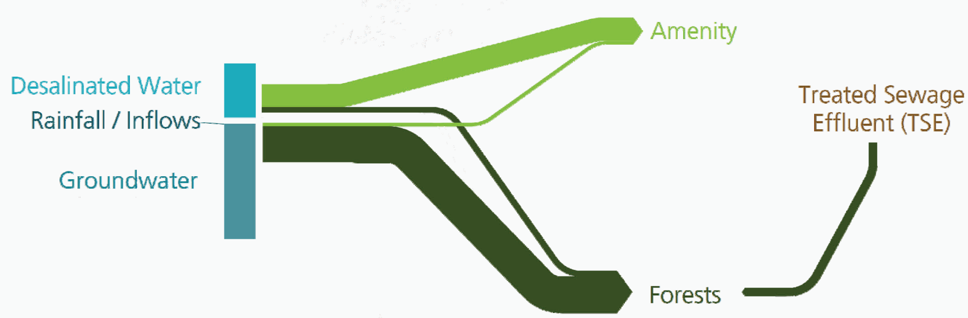
PUBLIC REALM

Sustainable urban development can assist a city in meeting long-term human and environmental needs. The public realm, defined as areas, including civic spaces and streetscapes, which the public can access and observe, is one such area in which Abu Dhabi can integrate urban development projects with sustainable community planning. As stated on the UPC website, "Plan Abu Dhabi 2030 presents a vision for a thriving and sustainable public realm for all citizens, residents and visitors of Abu Dhabi with particular emphasis on safeguarding natural resources and the cultural heritage of the city." In order to achieve the goal of sustainability, we suggest that areas that lie within the public realm (e.g., landscape, streetscape, parks and gardens, development projects, and fountain use) should be subject to a considerable degree of transformation.

Improvements made to these areas may serve two purposes: first, to reduce total water consumption and second, to send a signal that the government is serious about increasing water conservation.

This section describes strategies that fall under two strategic recommendations for public realm demand reduction:

1. Convert the composition of the public landscapes into sustainable ones
2. Improve irrigation efficiency of public spaces



The public realm sector is comprised of two main categories of consumption: amenity and forests, which draw water from three sources: desalinated water, groundwater, and TSE. Amenity plantations use an astounding 366 Mcm of desalinated water (43% of total) and 51 Mcm (3% of total) of groundwater used in the Emirate per year. Forests use even more total water, and siphon the 570 Mcm from groundwater (32% of total), 130 Mcm from TSE (71% of total), and 91 Mcm from desalinated water (14% of total). Because both amenity and forests consume so much of the natural water resources of Abu Dhabi, they present many opportunities for potential water conservation.

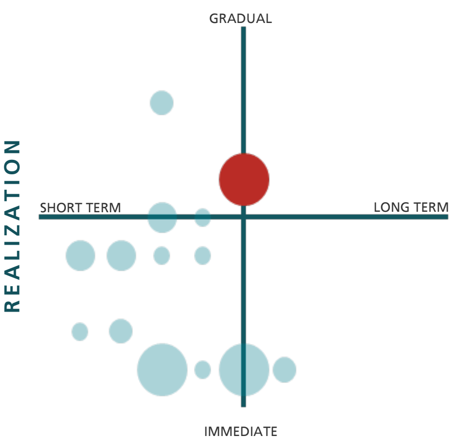
(Water Resources Master Plan, 2009)

RECOMMENDATION 1: CONVERT PUBLIC LANDSCAPES

The following section recommends and evaluates four strategies for converting public landscapes in the Emirate: first, we encourage the Emirate to use xeriscaping in all public landscape conversions; second, it we suggest that Abu Dhabi increase hardscaping; third, we suggest that all public fountains be converted into less water consumptive features; and fourth, we push the UPC to generate a landscape sustainability guide for all future developments.

STRATEGY 1.1: USE XERISCAPING

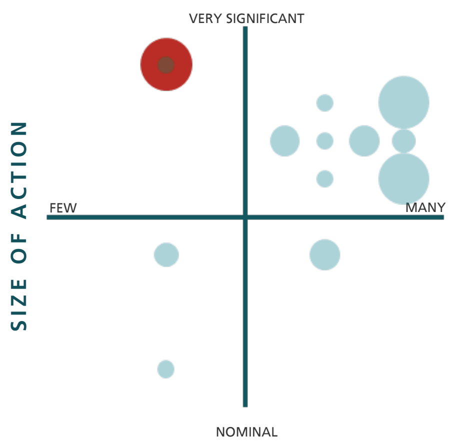
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 5-7 years
Realization: 7-10 years
Size of Impact: +100 Mcm

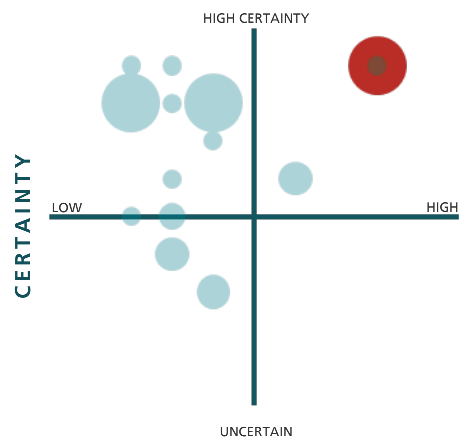
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 2-3 agencies (DMA, EAD, contractors)
Size of Action: Very significant
Size of Impact: +100 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 250-500 million Dh
Certainty: Very high certainty
Size of Impact: +100 Mcm

The EAD has already created a comprehensive manual cataloging the various native plants of Abu Dhabi, many of which can be used within streetscapes, parks, and gardens. We suggest that the Emirate begins using these native species to supplant all non-native plants within areas of the public realm. Further, the Emirate can employ a landscaping strategy called xeriscaping, which focuses on maximizing a landscape's aesthetic value while minimizing its water consumption. Xeriscaping uses strategies such grouping plants of similar water needs, using mulches rather than turf, and installing low-evaporation irrigation techniques, like drip hoses. In the near term, the Emirate can ensure that all new public developments to use native plants and xeriscaping techniques. Further, such new developments can serve as educational outreach locales to teach the public about xeriscaping and sustainable landscaping techniques. Over the next one to five years, the Emirate can begin to retrofit existing public spaces with xeriscapes. Alongside the guidance of the EAD, we believe that the Department of Municipal Affairs is best suited to oversee both the short and long-term initiatives.

Generally, the public realm has not incorporated features that promote sustainable use of water. A recent article published on March 30, 2010 says that the Municipality of Abu Dhabi City approved landscaping and irrigation plans of four major intersections that will include "400 extra palm trees and 172 trees of various types, as well as cultivating about 66 thousand square meters of green vegetation, flowers and ornamental trees." Though the plants are beautiful, initiatives like this do not pay heed to the scarcity of renewable freshwater resources. If a public awareness campaign were to be launched concurrent with proposals like the one above, the cognitive dissonance would undermine the efficacy of the sustainability campaign. Thus, we strongly encourage Abu Dhabi to coordinate campaigns and other initiatives across the Emirate.

There are some costs associated with converting the public realm into a climate-appropriate landscape. Lush, green landscapes are appealing to residents and visitors of Abu Dhabi and many stakeholders may resist changing the existing public realm features. But xeriscaping and arid landscaping techniques can produce verdant and luxurious public spaces, within the bounds of sustainability. Therefore, we suggest that all government agencies involved in the conversion of the landscape understand the necessity of these changes so that they can become proponents of the efforts. If there is no core support for these landscape conversions, then potential opposition will be more magnified.

These changes might also save money and energy in the long term (despite the high upfront costs of xeriscaping), by reducing landscape water use, decreasing maintenance costs, and decreasing desalination and groundwater pumping requirements. We recommend that the EAD and the DMA implement a study in the near-term to compare the levels of water savings by measuring water use differences between new xeriscape areas and unconverted areas. Such a study could provide a baseline to calculate potential conservation estimates for the Emirate if all spaces were converted to xeriscapes.

Evidence of Landscaping Retrofit Efficacy in California

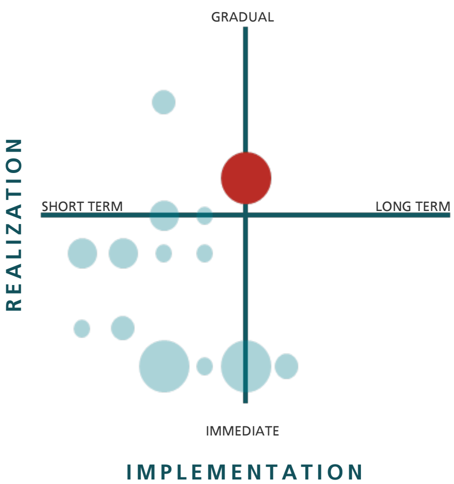
In 2009, the Eastern Municipal Water District, California, USA, as part of an effort to maximize water supplies, completed the Landscaping Retrofit Project. The Project commenced in 2005 resulting in a net reduction of water consumption by 75 percent from these areas, and is expected to reduce water use by an addition 10 percent. The significant reduction of water was attributed to the use of native plants and hardscaping materials.

(Eastern Municipal Water District)

Figure 2. The pictures on the right and left demonstrate analogous streetscapes before and after the Eastern Municipal Water District retrofit in California, USA.

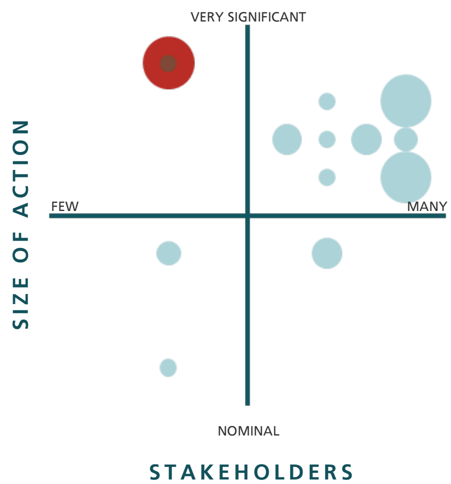
STRATEGY 1.2: INCREASE HARDSCAPING

TIMING OF IMPACT



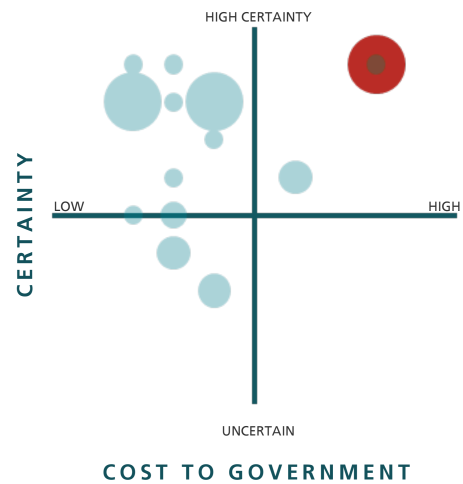
Implementation: 5-7 years
Realization: 7-10 years
Size of Impact: +100 Mcm

STAKEHOLDERS & SIZE OF ACTION



Implementation: 5-7 years
Realization: 7-10 years
Size of Impact: +100 Mcm

COST & CERTAINTY



Implementation: 5-7 years
Realization: 7-10 years
Size of Impact: +100 Mcm

We suggest that the Department of Municipal Affairs also adopt sustainable hardscaping methods. There are multiple definitions of "hardscaping," but for purposes of this paper we define is as "the non-living functional elements of a garden such as paths, seating, and edging. Sustainable hardscape materials should come from recycled materials, be non-polluting, and, if possible, be produced locally to avoid excessive use of non-renewable energy sources such as petroleum and coal. Furthermore they should prevent soil erosion, water run-off, and last a long time before needing to be replaced."

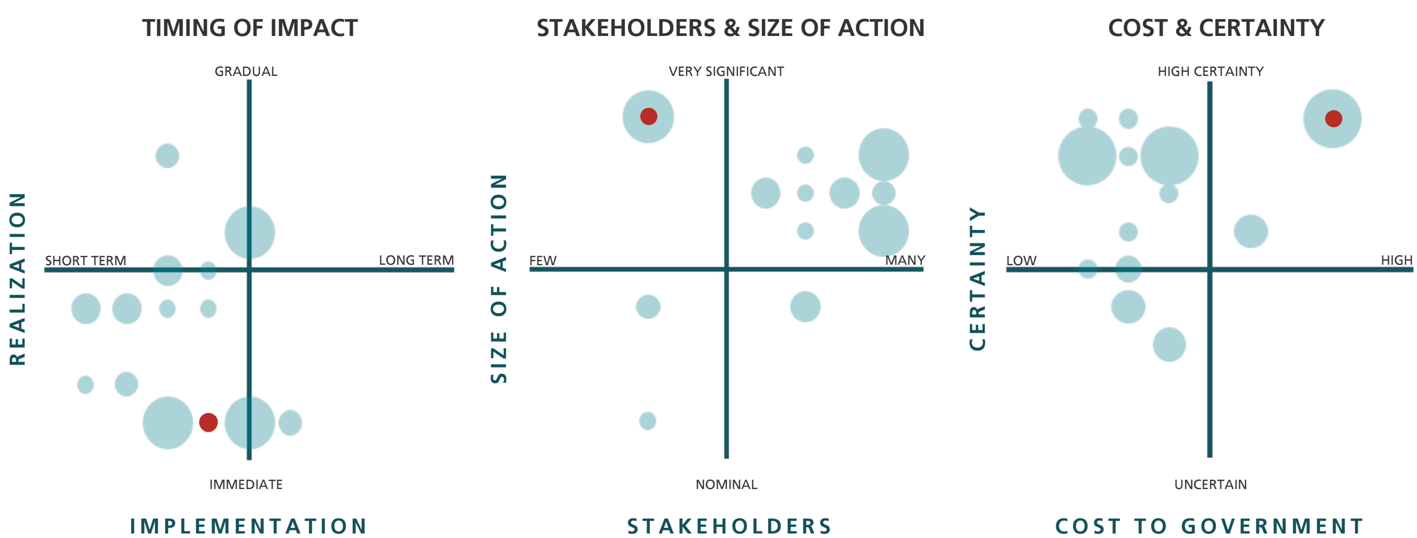
Hardscaping strategies are used in Masdar City, which is currently producing wood chips on-site that are made from residual construction material. The water requirements in the region can be further reduced by retrofitting turf grass with other materials including cobble, crushed rock, decomposed granite, boulders and concrete.

Figure 3.
Scrap construction materials at Masdar City are collected, sorted, and processed. Scrap wood materials are converted into wood chips, which can be used for various purposes, including hardscaping.

This strategy can be implemented immediately to ensure that all new developments increase the percentage of their outdoor territories with hardscape material in conjunction xeriscaping and native planting. As with xeriscaping, long-term conversions will likely take place over one to five years from implementation, retrofitting water excessive plants within the public realm with either native plants or aesthetically appealing hardscape materials (depending on location). Both the short and long-term strategies should be overseen by The Department of Municipal Affairs.

Although increasing the percentage of hardscape will decrease the use of water for non-native landscape, there are certain costs associated with placing too much hardscape within Abu Dhabi. Hardscape materials have various effects on the environment; they do not absorb water, unlike soil or natural surfaces, and as a result, increase the amount of water runoff during torrential rainstorms, such as the one in early March 2010. Hardscape runoff, especially from urban areas, often contains contaminants and can be a cause of non-point source pollution which may ultimately be discharged into receiving waters (i.e., Arabian Gulf). Such issues can be mitigated by mixing hardscapes and xeriscapes alternatively in an area, giving runoff ample natural buffers to prevent heavy pollutants being carried to groundwater or the Gulf.

STRATEGY 1.3: MAKE FOUNTAINS MORE SUSTAINABLE



Implementation: 3-5 years
Realization: 0-1 years
Size of Impact: 0.1-1 Mcm

Stakeholders: 2-3 agencies (DMA, EAD, contractors)
Size of Action: Very significant
Size of Impact: 0.1-1 Mcm

Cost to Government: 250-500 million Dh
Certainty: Very high certainty
Size of Impact: 0.1-1 Mcm

Water can and should continue to be a feature in Abu Dhabi's urban landscape; the question is how and in what volumes. Nonfunctional and artful water use in all cities is important and particularly so in the arid Middle East; urban fountains serve to absorb noise and particulate pollution, and even act to cool the immediate vicinity, albeit very slightly. Smaller trickling fountains are less prone to evaporative waste and can serve many of the same functions of a larger, grandiose fountain. We challenge

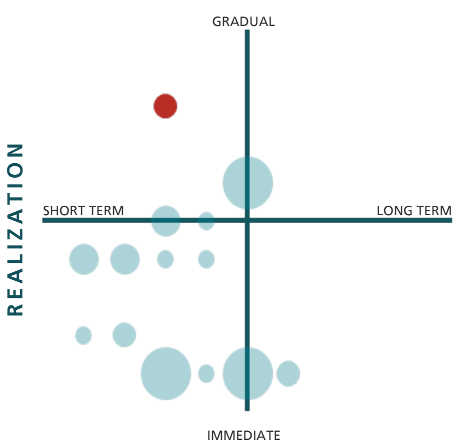
Abu Dhabi's urban designers is to develop a scheme that marries functional and non-functional water use—aesthetic water infrastructure that allows water to feature in the urban landscape, but in a manner that does not allow it to wastefully evaporate. Such an endeavor will allow fountains and water architecture to continue to serve as a source of pride, by showcasing Abu Dhabi's sustainable design and ingenuity. These efforts can include encasing fountains in glass and making water infrastructure, such as TSE pipes, artful architectural features on the urban landscape. These new features too, can serve as a means to educate the public on the Emirate's sustainability efforts. This, however, is a long-term vision and must be reconciled with architectural, engineering, and fiscal realities.

In the short-term, efforts can focus on high-volume and high-pressure fountains, which are commonly found around the Emirate. They use significant amounts of water, and despite the fact that many of these fountains use treated sewage effluent (TSE) water, the portrayal of excessive water on a city level contradicts the reality of the serious water problem.

Decreasing the relative volume and size of fountains that are to be constructed, and reducing their abundance would assist in managing the supply of water in the region. Fountains with low volumes, coupled with artful xeriscaping can be important urban centerpieces for the city. We recommend that fountain design and usage be overseen by Estidama in conjunction with the Abu Dhabi Water & Electric Authority (ADWEA), responsible for overseeing the volume and source of water used, and the DMA. We suggest that these agencies also develop a schematic of how developers can reduce the water consumed by large water structures and contract urban designers and architects to develop sustainable water structures. The schematic may address the size and the source of water for the fountains. We believe that this initiative could be up and running within two years and that it can realize substantial gains within five years.

STRATEGY 1.4: CREATE A SUSTAINABLE LANDSCAPE GUIDE

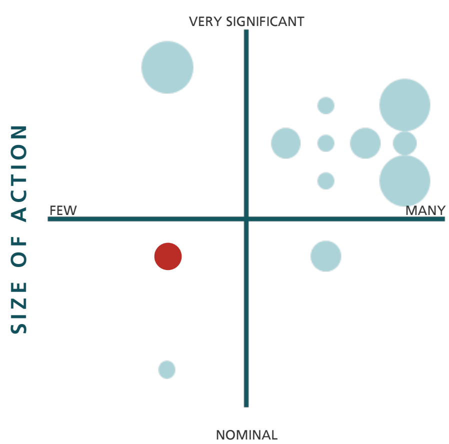
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 2-3 years
Realization: 13-16 years
Size of Impact: 1-5 Mcm

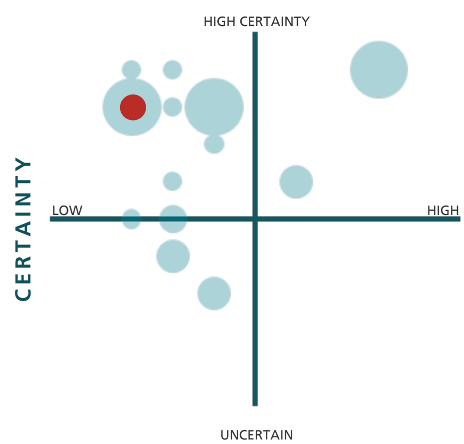
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 2-3 agencies (DMA, EAD, contractors)
Size of Action: Modest
Size of Impact: 1-5 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 1-10 million Dh
Certainty: High certainty
Size of Impact: 1-5 Mcm

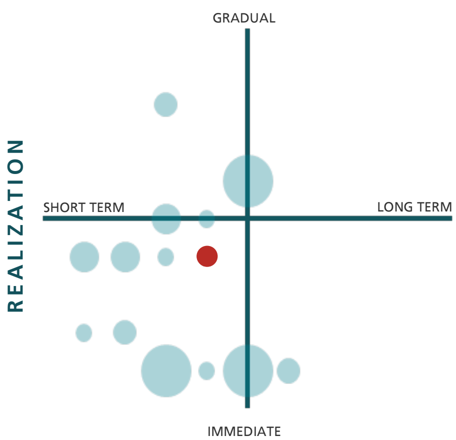
We propose that within one year the UPC, the EAD, the DMA, and developers collaborate on charrettes and urban design workshops on sustainable landscaping. Over the longer-term (roughly three years), the UPC can develop a design manual of desert landscaping and xeriscaping for all commercial and corporate developments. This manual can represent a collaboration between the UPC and associated developer stakeholders. Likewise it could also serve as a blueprint for developing aesthetically pleasing landscapes in tune with the natural environment of the Emirate by including, for instance, the aforementioned list of plants created by the EAD. Similar initiatives have taken place in other arid regions. For example, in 2007, the city of Santa Rosa California developed a "Water Efficient Landscape Policy" in order to establish "standards for landscape design appropriate to Santa Rosa's climate, soils, water resources, land use and resource planning."[145]

RECOMMENDATION 2: IMPROVE PUBLIC SPACE IRRIGATION EFFICIENCY

To realize the water conservation gains from converting public spaces to xeriscaping and hardscaping there must be both a reduction in and improvement of the methods for irrigation. Overconsumption of water in the Emirate comes largely from systemic and avoidable inefficiencies, such as unnecessary water loss from evaporation due to poor irrigation scheduling. The public realm can be greatly improved for water sustainability, representing occasion to showcase Emirate sustainability efforts to residents and the region. The following section recommends and evaluates two strategies for improving irrigation in public spaces of the Emirate: first, we suggest that the Emirate avoid daytime irrigation, and second, that all appropriate spaces be irrigated with greywater.

STRATEGY 2.1: ESTABLISH IRRIGATION SCHEDULING

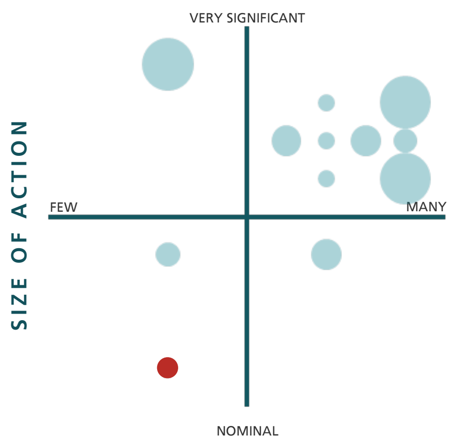
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 1-5 years
Realization: 3-5 years
Size of Impact: 0.1-10 Mcm

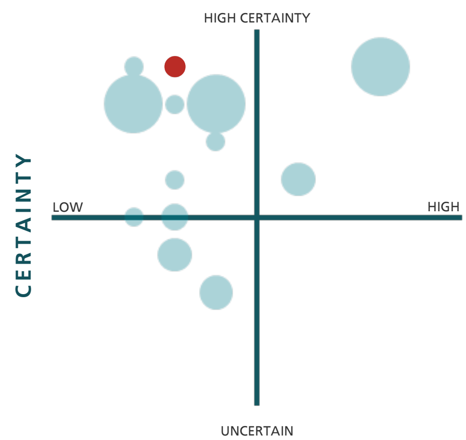
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 2-3 agencies (DMA, EAD, contractors)
Size of Action: Nominal
Size of Impact: 0.1-10 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 10-25 million Dh
Certainty: Very high certainty
Size of Impact: 0.1-10 Mcm

Irrigation scheduling is the method of establishing irrigation volume and timing.[146] We suggest that the Department of Municipal Affairs create strict irrigation-timing regulations within the Emirate, a project that can be implemented soon and at little cost. Optimal irrigation hours are in the early morning hours (before 9:00 AM) and in the early evenings (after 6:00 PM). Over the next one to five years, the DMA can map out the irrigation systems on an Emirate level and allocate specific timings and volumes for landscape irrigation concurrent with the xeriscaping project. Different plants require different amounts of water; a tenet of xeriscaping is to group plants with similar water needs, which can help to inform how much irrigation is needed where and when. In generating a longer-term vision and schedule for irrigation, the DMA would have control on reducing water consumption that is wasted through evaporation (due to irrigation during daytime), leakage, and water loss. The irrigation scheduling in the short-term can be focused on gardens, parks and the general public realm. In the future, this initiative can be implemented in the landscaping of all major developments, commercial, and corporate areas.

STRATEGY 2.2: USE GREYWATER FOR IRRIGATION

We suggest that property under the care of government-owned or -leased buildings use treated greywater for irrigation purposes. This would require government buildings to install greywater collection and treatment capacity. The respective government agencies can to coordinate with the Regulation and Supervision Bureau to be granted approval for on-site safe greywater treatment for irrigation purposes. Greywater for landscape can assist in reducing the use of potable water. For example, a study estimates that an average household in Arizona, USA generates approximately 113,000 to 151,000 liters of greywater per year.[147] This indicates that government buildings and other municipalities in the region have the potential to significantly contribute to the reduction of potable water for irrigation.

Although water recycling has been proposed as a method of increasing water supply, there have been many obstacles in implementing water-recycling programs. One such obstacle is the cost of providing recycled water, which is more expensive than other sources. The "low price of water is an impediment to recycling and utilizing stormwater. A more realistic pricing would likely discourage wastage, while simultaneously, encouraging the adoption of water efficient devices, as a more authentic reflection of the vulnerability and variability of supply."[148]

One way to minimize the cost of greywater is to decentralize recycling by performing recycling at the source. This could save funds from being allocated to materials, energy use and water transfer infrastructure. Further, water collected and recycled from runoff capture can lead to reductions in levels of non-point source pollutants entering downstream.

An additional issue with recycling is dealing with public acceptance. Certain Australian communities have been averse to municipal water recycling, particularly when domestic water uses are involved. Australia's experience with treated greywater is instructive: if such a policy is to be implemented in Abu Dhabi, at a decentralized level, then the respective government agencies will likely need to address potential public misconceptions and disagreement. This can be addressed by educating the public on water management options.[149]

Case Study: Australia

The seven-year drought in Australia and policy geared toward urban water restrictions have assisted in increasing public's attention on the limitations of urban water use. In reaction to the limitations of water use, urban water recycling has been noted as one of the means to address water sustainability in the capital cities. Recycling can supplement water use in areas that drinking water application is not required. In Australia, approximately 1-4 percent of residential potable water is used for drinking, while majority is used for gardens and sanitation.

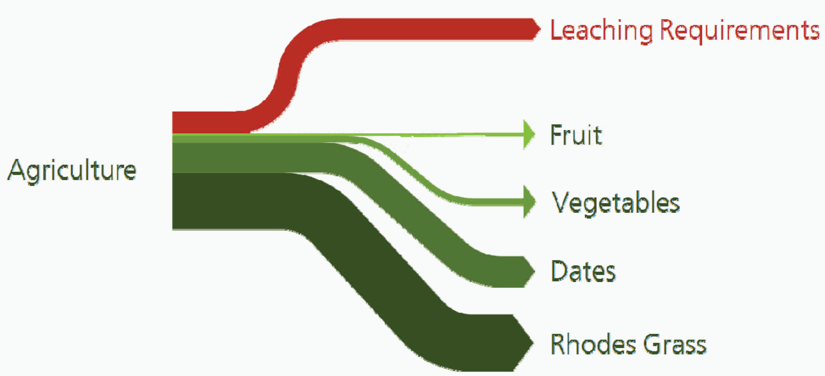
(Nyree Stenekes, Hal Colebatch, David Waite, and Nick Ashbolt, "Risk and Governance in Water recycling: Public Acceptance Revisited," *Science Technoloy and Human Values* 31, no 107 (2006))

AGRICULTURE INDUSTRY

Representing approximately 45% of total water consumption[150] and 64% of groundwater consumption[151], the agriculture sector is a major consumer that must be included in efforts to ensure Abu Dhabi's sustainable water future. Farming is a relatively new industry for Abu Dhabi, emerging from heavy government subsidies for water and energy. For example, Rhodes grass alone receives over 800 million dirham annually.[152] However, the current incentives do not dovetail with national strategies for reducing water consumption and eliminating the use of desalinated water in agriculture. To foster responsible water consumption, we suggest that Abu Dhabi find a way to reduce water used in the agricultural sector.

Though the fact that conservation efforts should focus attention on agriculture holds true, a divergence occurs in determining the best strategies to tackle high water consumption. The sector contributes little to the country's GDP[153], but it has become a source of livelihood for many residents, especially in rural areas. From an objective perspective, the decision to minimize agriculture for environmental sustainability is a logical and necessary one. However, politicians and civil servants responsible for maintaining high quality of life standards for their citizens may find such a decision challenging; repercussions of eliminating agriculture would be felt socially and politically unless reasonable alternative income sources are developed. Examples of ideas currently being discussed in Abu Dhabi include vesting farmers in greenhouse -based agricultural companies and giving farmers oil shares. If implemented, such strategies would address agriculture's high consumption and focus on long-term sustainability. In the interim, maximizing efficient water use on existing farms is a valuable first step in reducing agriculture's water demand.

This section describes two strategies that fall under one strategic recommendation for agricultural demand reduction: improving the water efficiency of existing agriculture.



Since agriculture consumes 64% of all groundwater, it is worth understanding the crops that use the 1,013 Mcm per year. Rhodes grass, grown solely for fodder, uses 59% of groundwater, dates use 32%, and other fruit and vegetables together use 9%. Leaching requirements account for 13% and indicate another area that could potentially realize higher rates of conservation if given appropriate attention.

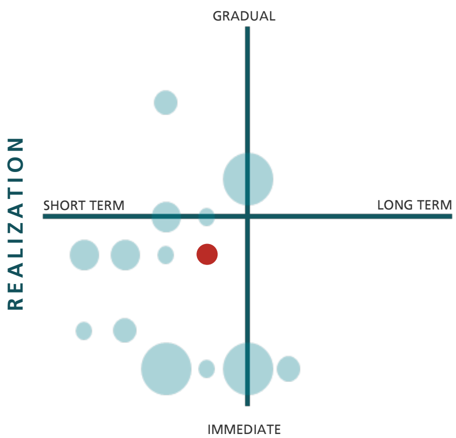
(Water Resources Master Plan, 2009)

RECOMMENDATION 1: IMPROVE AGRICULTURAL EFFICIENCY

Improving agricultural water efficiency is a tremendous challenge for the Emirate—the agricultural sector is largely decentralized and, thus, difficult to regulate effectively. Outreach is important and likely very difficult to achieve via the public awareness campaign outlined above. Instead, due to the technical nature of the variables involved, this section evaluates the efficacy of establishing agricultural innovation and extension centers as a means to educate farmers about water scarcity and implement water conservation best practices.

STRATEGY 1.1: ESTABLISH INNOVATION CENTERS

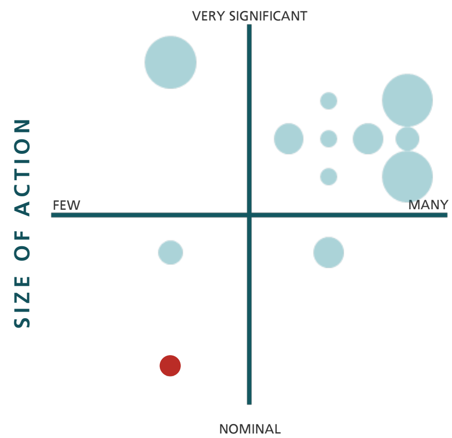
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 1-5 years
Realization: 3-5 years
Size of Impact: 0.1-10 Mcm

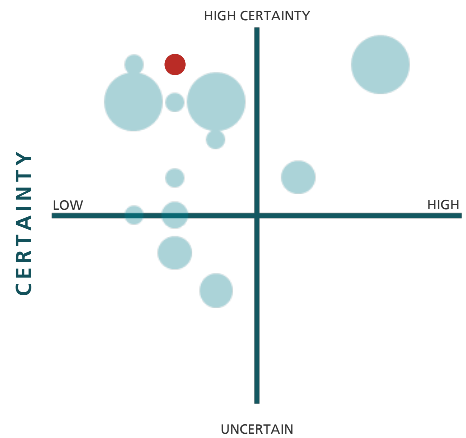
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 2-3 agencies (DMA, EAD, contractors)
Size of Action: Nominal
Size of Impact: 0.1-10 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 10-25 million Dh
Certainty: Very high certainty
Size of Impact: 0.1-10 Mcm

We recommend that the Emirate help establish agricultural innovation and extension centers responsible for developing water conservation techniques and sharing them with farmers.

This strategy shifts incentives through two critical, simultaneously implemented approaches: (1) reduction of direct government subsidies to farmers; and (2) development of incentives that foster higher water conserving farming techniques.

In order to facilitate more efficient farming practices, the Emirate can undertake the creation of agriculture innovation and extension centers. The goals of the centers are intended to: (1) identify problems in production; (2) study and to pilot farming practices aligned with great efficiency in terms of water and other natural resources consumption and waste; and (3) function as a clearinghouse on best practices in sustainable agriculture for the farming community within and outside of the Emirate.

Specifically, such centers would be responsible for the following:

- Researching modern irrigation techniques
- Researching new crop species
- Sharing all findings with the agriculture community
- Conducting field-level training for farmers
- Achieving high levels of participation and awareness in their regions

We also suggest that the agriculture innovation centers be holistic in their design to support collaboration between and among important stakeholders. Centers would house, for example, offices, dormitories, laboratories, farming lands, potential greenhouses or shadehouses, and conference facilities together in campus-like settings. Thus, as knowledge emerges through research and applied research, demonstration of water sustainability within the agriculture sector is more likely to be captured and disseminated. One idea is that the centers can be run through the university system and will become extensions of the current agriculture programs staffed by agriculture researchers working in collaboration with local farmers.

Total cultivated area in Abu Dhabi is estimated to be 70,375 hectares spread throughout multiple major agricultural regions: the Liwa crescent in the Western Region, the northeast Abu Dhabi region, and the Eastern Region (see Figure 4).[154] Each region has different climatological, hydrological, and geological environments that impact agriculture and should be studied locally.[155] Currently, the United Arab Emirates has four research stations, but only one located within the Emirate of Abu Dhabi: the Agricultural Research Directorate centrally located in Al Ain.[156] In addition to the ARD, the Al Ain municipality also has the Agricultural Research Center, which is focused on food and industrial crops, forage resources, and animal production.[157] Although some research centers already exist, officials have expressed a need for increased communication from lab to farm. Similar to the International Center for Biosaline Agriculture (ICBA)[158] located in Dubai, the centers will become hotbeds for agricultural techniques and will help spur the image of innovation in the Emirate.

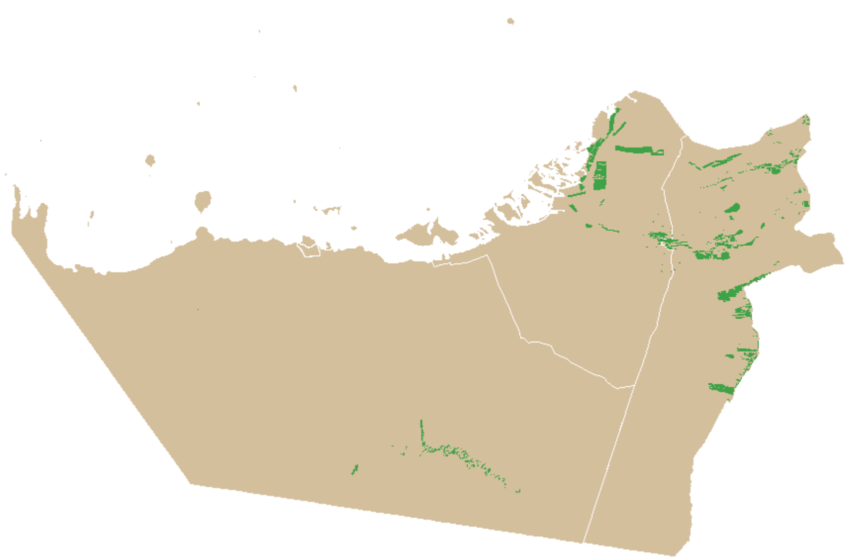


Figure 4.
Farms in the Emirate of Abu Dhabi shown in green, 2009. (UPC)

From planning to opening, the centers can be erected within two to three years of government approval. After construction, they will need to conduct experimentation and share techniques with the community, which may take upwards of six to seven years until consistent water reduction is realized.[159]

We suggest that in the early stages there be three to five centers, some located in the Western Region and the remainder located throughout the Eastern Region. The cost to the government will likely be high in the planning, construction, and staffing phases. In order to plan, construct, and staff the first centers, we recommend that the government shift a portion of the energy and crop subsidies for Rhodes grass to funding the centers. Reducing subsidies for Rhodes grass may negatively impact farmers by raising the costs of operating, but these costs will likely be partially offset by the gains in efficiency generated by the research of the centers. One alternative to this strategy may be to slowly reduce the subsidies given to the agriculture sector, but this would potentially raise concerns of decreased food self sufficiency. Grant money allocated for research at the centers can be channeled either through the university system or through the centers, both have worked in practice.[160]

Case Study: University of California, Riverside Agriculture Research Institute for Deserts (ARID)

ARID was founded over 50 years ago in Riverside, California, a region with a similar climate to Abu Dhabi. The objectives of ARID are to:

- Foster and coordinate interdisciplinary programs on agricultural issues relevant to desert environments
- Convene and coordinate rapid response teams to address new or developing agricultural problems
- Function as an outlet for the transfer of technology and information to the public on desert agriculture issues
- Serve as a focal point for research, service, and educational programs in deserts
- Initiate and expand linkages with other stakeholders in desert agriculture
- Attract support for programmatic activities through grants, contracts, donations, and endowments

Part of ARID, the Desert Research & Extension Center (DREC) fosters over 50 research projects on roughly 100 hectares of land. In combination with the FARM SMART program, DREC conducts over 150 trainings for about 7,800 students every year.

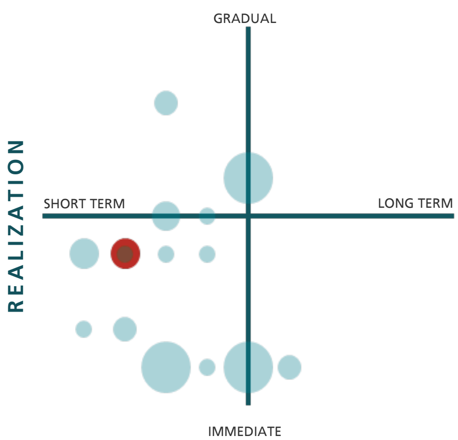
(Desert Research & Extension Center, "About ANR Desert REC," ANR Desert Research & Extension Center, http://groups.ucanr.org/desertrec/)

Figure 5. A desert research & extension center of the University of California, Riverside Agriculture Research Institute for Deserts.

For the first few years of implementation there may need to be concerted efforts to build the participant base and to fine-tune participation incentives so that farmers are inclined to participate. Research into extension education has found that farmers retain knowledge taught through in-person meetings and prefer interaction over written materials alone.[161] According to the 2005 Census, there are roughly 65,000 people labeled "Agriculture Ordinary Workers" or "Growers of Mixed Crops"; it is estimated that 51% of those workers are illiterate.[162] Therefore, we suggest that these centers be spread throughout the Emirate, that they have enough staff to meet the heavy communications requirements, and that they make demonstrations of better farming techniques directly to farmers. To incentivize participation, the centers may use part of their funding to create a certificate program that provides prestige and modest agricultural aid to farmers who have completed all relevant trainings of the certification program. Agricultural aid may take the form of advanced irrigation systems, new types of crops, or other innovations.

STRATEGY 1.2: ESTABLISH STANDARDS FOR ALTERNATIVE WATER SOURCES

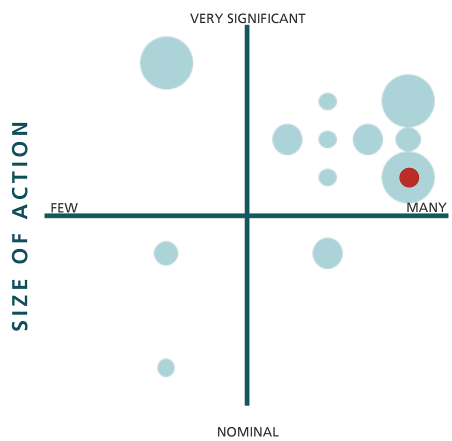
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 1-2 years
Realization: 3-5 years
Size of Impact: 5-10 Mcm

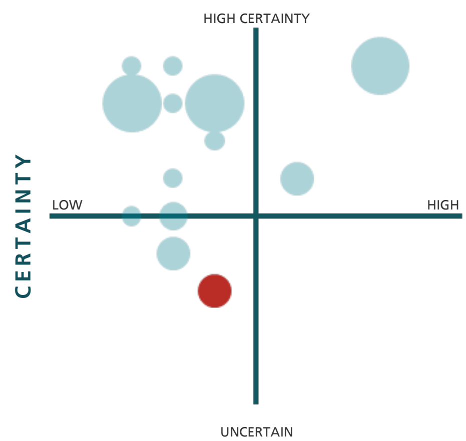
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: Roughly three agencies / stakeholders (RSB, EAD, MAF)
Size of Action: Modest
Size of Impact: 5-10 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 1-10 million Dh
Certainty: Somewhat uncertain
Size of Impact: 5-10 Mcm

Currently, treated sewage effluent (TSE) is used for irrigation for amenity plants and forestry. Based on the 2009 Master Plan, the future urban uses for TSE exceed supply.[163] However, as the Emirate shifts toward public realm xeriscaping and reviews its current irrigation practices, remaining TSE can be available for agriculture. Currently, excess TSE water not used in amenity or forestry is ultimately discarded into the desert. In 2007, there were 51 million cubic meters of water discarded because the TSE irrigation systems were functioning at capacity.[164] Rather than discarding the excess, if that water could be further processed, it could be used in agriculture with the development of use-specific water quality standards.

Implementing standards for use-specific water quality creates the regulatory framework for future TSE use. International guidelines exist and serve as a starting point for developing Emirate TSE standards.

Specifically, the World Health Organization (WHO) standards for wastewater in agriculture states that any reuse needs to take into account the cultural beliefs as well as public perception.[165]

To plan and implement a program, there are eight criteria that need to be assessed, including:

1. Health
2. Economic feasibility
3. Social impact and public perception
4. Financial feasibility
5. Environmental impact
6. Market feasibility
7. Institutional feasibility
8. Technical feasibility[166]

While the Emirate has the financial capability to adhere to international standards, it is equally important to inform the population about wastewater in agriculture. The World Health Organization conducted a survey of farmers and the general public in Palestine on the use of wastewater in agriculture. Their study found that respondents believed it was acceptable in Islam to use wastewater; if there was a drought or scarcity – it was justified to be used for irrigation. Additionally, respondents were willing to consume items grown with treated wastewater. Public perception, as well as acceptance, could be reached through wastewater treatment demonstrations and public outreach efforts.[167]

Alternatively, the Emirate could revamp its sewage system to have separate systems for greywater and black water. Currently, all sewage is processed through one system.[168] The current sewage system needs to be examined in light of the growing population needs. Any capital improvement needed to sustain the Emirates' growth can present opportunities to redesign the system. This would allow greywater to be used multiple times in the urban setting such as to wash clothes, flush toilets, and then later be used for agriculture.

Using Wastewater for Agriculture

The untapped opportunity to use wastewater is not unique to the Emirate. Other countries in the Middle East have not yet examined the potential benefits of using wastewater. Throughout the region, countries have been working to extend the sewage system and treatment capacities. Similar to the Emirate, any collected wastewater that is not used is discarded. Societal perceptions have limited the demand for wastewater in the Middle East. However, countries such as Jordan and Tunisia have suggested the use of TSEs in agriculture, forestry, and groundwater recharge. With proper treatment, wastewater can be reused in agriculture

Other countries are working to privatize wastewater utilities. Saudi Arabia is working on a 15 city plan to develop wastewater infrastructure. Saudi Arabia has implemented wastewater reuse standards. It currently reuses 18% of the 1.84 million cubic meters of wastewater daily. Water reuse can be utilized for agriculture and landscaping which will help communities stretch their freshwater supplies. Many countries in the Middle East are aiming for 100% reuse of TSE in the next few years.

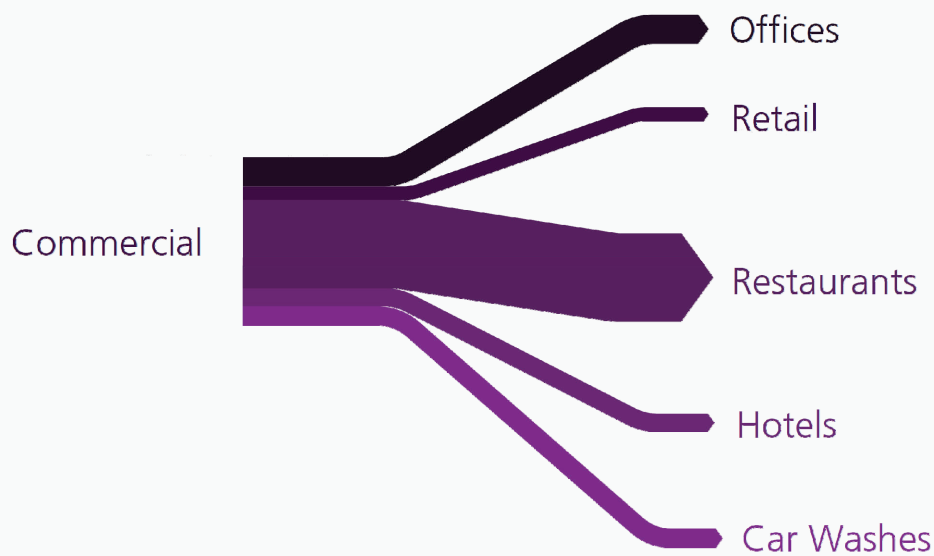
(The World Health Organization; Vivek Gautam "Quenching the Middle East's Thirst" *Water World*, 25, Issue 1, March 1, 2010; Nadia Abboud, "Middle East gears up for water reuse technologies" *Water World*, 25, Issue 1, March 1, 2010)

TOURISM INDUSTRY

Abu Dhabi relies heavily upon the tourism sector, which employs roughly 9.7% of workers in the Abu Dhabi Emirate, representing roughly 108,000 jobs, and generates 3.6% of the gross domestic product.[169] The Emirate has positioned itself as a leader in hospitality and provider of some of the most luxurious hotels in the world. As the industry grows from 1.8 million visitors per year to roughly 8 million by 2030, so will its water usage. The North Carolina Division of Pollution Prevention and Environmental Assistance (DPPEA) suggests that the water footprint for the typical U.S. hotel is approximately 825 liters of water per occupied room per day[170] and a national survey suggests that luxury hotels consumed close to 947 liters of water per room per day.[171] Dubai hotels use between 650 to 1,230 liters of water per guest[172] with the more luxurious hotels typically consuming more water. It is projected that the number of hotel guest rooms in Abu Dhabi will increase by 95% and annual tourist visits will increase by 64%.[174] Although the number of residents is expected to increase, a significant portion of water usage will be consumed by visitors. Therefore, Abu Dhabi has the opportunity to conserve large amounts of water in this sector and improve the long-term viability of the Emirate.

The tourism sector represents a tremendous opportunity to increase water conservation throughout the Emirate. Below we focus on two core areas for strategic focus in the tourism sector, each with strategies aimed at the goal of reducing water consumption:

1. Create incentives for water conservation
2. Increase efficient water use



Hotels, a primary component of the tourism sector, consume roughly 2 Mcm per year in Abu Dhabi. Though other pieces of the sector consume more water per year, the tourism industry has the potential to greatly improve its current water conservation efforts.

(Source: Water Resources Master Plan, 2009.)

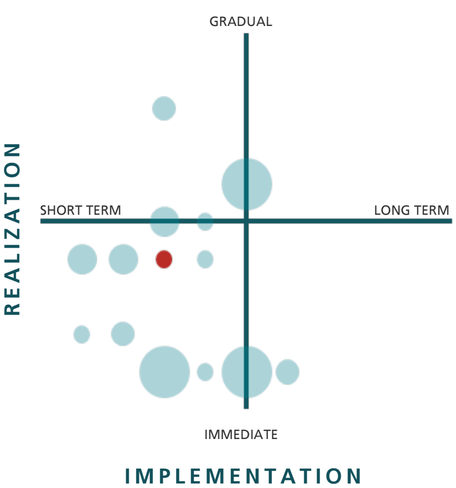
RECOMMENDATION 1: CREATE WATER CONSERVATION INCENTIVES

Creating the incentives for the tourism industry to reduce consumption can be analogous to inducing behavior changes in the residential sector, though with several important differences. First, water consumption can be more easily linked to tariffs in the tourism sector than in the residential sector. Second, economies of scale and diligent financial analysis within the industry help its leaders properly evaluate the benefits of water conservation. However, a centralized regulatory framework for evaluating, monitoring, and rating water conservation and sustainability within the industry may have greatest effect in reducing consumption while making Abu Dhabi a sustainable tourist destination.

The following section recommends and evaluates three strategies for generating incentives to reduce water consumption in the Emirate's rapidly expanding tourism industry: first, that all hotels should fall under the new Pearl Rating certification system and the Pearls should be used as criteria for hotel star ratings; second, that the Emirate can award rebates to those hotels installing water efficient technologies; and third, that the Emirate can award rebates for hotels converting their landscapes to sustainable xeriscapes.

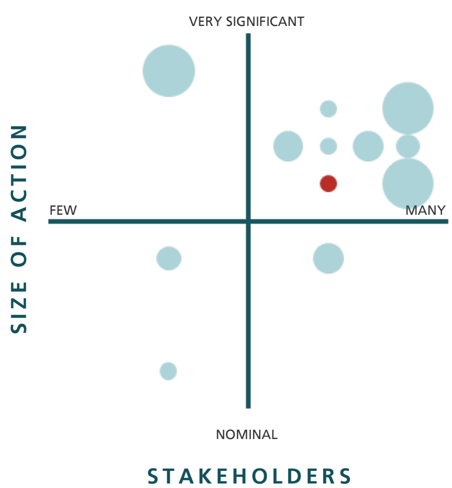
STRATEGY 1.1: CREATE AND INCORPORATE HOTELS INTO PEARL RATING SYSTEM

TIMING OF IMPACT



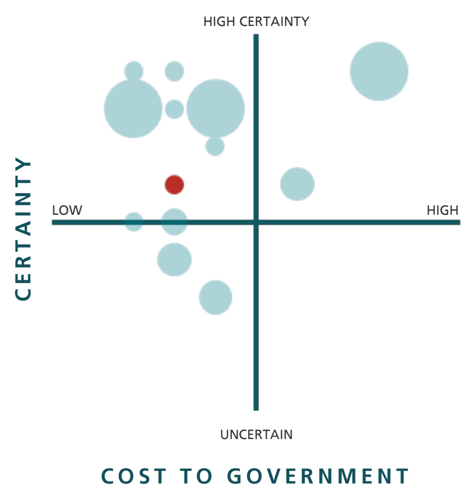
Implementation: 2-3 years
Realization: 3-5 years
Size of Impact: 0.1-1 Mcm

STAKEHOLDERS & SIZE OF ACTION



Stakeholders: 2-3 (UPC, ADTA, hotels, etc.)
Size of Action: Significant
Size of Impact: 0.1-1 Mcm

COST & CERTAINTY



Cost to Government: 10-25 million Dh
Certainty: Average certainty
Size of Impact: 0.1-1 Mcm

We recommend that the Pearl Rating System become a government-mandated policy and be incorporated into Abu Dhabi regulations for existing and future hotels and resorts. Revisions to the existing system will be necessary to ensure compliance within this sector. These revisions include, but are not limited to, redefining Pearl levels and the requirements to achieve such levels for hotel eligibility, determine minimum standards for tourism licensing, define hotel classification ratings, and create subsidy structures to assist with compliance. We believe that the Abu Dhabi Tourism Authority (ADTA), as acting statutory body, and primary promoter and developer of the tourism industry, is best suited to be the responsible agency for amendments, implementation, monitoring, and enforcement of such regulations.[175]

In an effort to promote water conservation in hotels and resorts, the Abu Dhabi Emirate can reposition itself as a marketable destination based on its efforts to reduce overconsumption of water resources. We recommend that the ADTA's official mission statement include the word "sustainably" to provide vision of such priorities:

> To drive and support the development and promotion of tourism in Abu Dhabi efficiently, effectively, ***sustainably,*** and transparently, in partnership with all our stakeholders while ensuring the highest quality standards.[176]

Division of responsibilities within ADTA are recommended as follows:

- **Strategy and Policy Division:** Amend and mandate as a new regulation, a hotel/resort-specific Pearl Rating System (based upon the existing Estidama building code system) and redefine the hotel classification ratings dependent on the number of Pearls achieved. Hotel classification ratings are expressed in either Stars or Diamonds worldwide and based upon the ADTA's Hotel Establishment Statistics; the Emirate abides to the Star ratings classification.[177] The Pearl Rating System will be amended to include specific water-efficient technologies, strategies, and water demand reduction requirements to be met in order to achieve 5-star, 4-star, and 3-star status. The higher the classification ratings, the more Pearls required to retain such standing, (e.g., 5-star status will require more Pearls than a 4-star status). It should be noted here that in order to retain/attain the elite 5-star status, the strictest requirements and highest technologies will be mandated and therefore earn the highest pearl rating. For example, if each pearl equates to a star rating, then the 5-star status will need a minimum of 5 pearls. If it is mandated that greywater systems and condensate recovery systems be implemented to achieve 5 pearls, then these technologies will need to be implemented to receive the full 5-star recognition.[178] Star classification ratings are significant in the hotel industry to make distinctions in prestigious standings worldwide and provide an important basis on which hotels are graded.[179] Abu Dhabi will be looked upon as a premier destination that takes water conservation seriously. A newfound perception that water conservation services are, in fact, luxury services, can increase tourism and economic development.

- **Tourism Standards Division:** Amend tourism-licensing requirements (both new licenses and renewals) to mandate a minimum number of pearls in order for a hotel or resort to be operational. Each license will indicate the Pearl rating and the hotel classification rating achieved. Neither a license to operate in Abu Dhabi will be permitted nor a hotel classification rating awarded, until the minimum requirements are met according to the ADTA. Licensing standards should be communicated to all stakeholders affected by the regulation through training seminars. Furthermore, existing hotels and resorts can be given ample lead time to comply with the regulation to maintain their license validity and hotel classifications. Two to four years[180] or more from the time that such regulation is officially enacted may be sufficient, but will ultimately be determined according to what the ADTA deems necessary. After determined lead time has passed and the hotel/resort has achieved minimum standards to be operational but not the minimum to reach their designated star status, the hotel has the option to either (a) continue operating at a reduced classification rating or (b) remain non-operational without a license until minimum requirements for the necessary rating are reached.

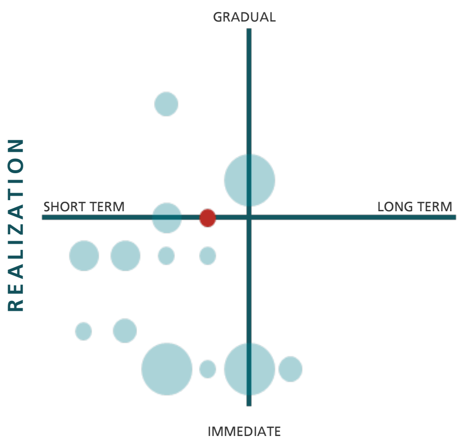
- **Marketing and Promotion Divisions:** Work with destination management companies and international tourism centers to promote Abu Dhabi as an eco-friendly and water conservation-focused destination. Promote the preservation of the Arabian Gulf habitat without over-consuming water resources while delivering the highest standards of luxury service in the UAE. National and international campaigns may be developed and maintained on a consistent basis to promote awareness of Abu Dhabi's new practices and regulations to UAE residents and to the world. As a leader and the capital of the UAE, Abu Dhabi will have the ability to encourage and influence regulation particular to reducing water demand and increasing supply strategies within the other Emirates.

At this time there is no known regulation in place mandating hotel compliance for water conservation; enforcing one will require the help of the government through both international recognition and subsidies. The majority of hotels today voluntarily retrofit their buildings so they can sharpen their image, beat the competition, and improve the perception of the company and its corporate social responsibility. One example of a leader in sustainable technologies is The New York Marriott Downtown Marriott in New York City. They installed their own tri-generation plant, which allows the hotel to generate its own electricity, cooling, and heating on-site, producing enough electricity to power up to 700 homes.[181] The hotel also has their own water filtering system on site, making it one of the most energy and water efficient hotels in the Marriott portfolio. The General Manager confirms that there are neither incentives nor tax write-offs to fund such projects and that the needed capital is generated by the hotel owners and approved by Corporate Headquarters,[182] thus there is slow integration of the technologies to meet increased demand. If there were regulations and subsidies in place to increase the implementation of these technologies, then the impact expected on resource conservation may be huge. The strategy recommended above could take all hotels to the next level in reducing water consumption.

In an effort for existing hotels to comply with amended standards and maintain current hotel classifications, we recommend that the Abu Dhabi Emirate offer subsidies which can be used to retrofit new technologies and implement required strategies (as needed) to maintain classification standards. We suggest that subsidies be allotted for current hotel ratings and not when a hotel/resort wants to change its star-rating classification.

STRATEGY 1.2: CREATE A WATER-EFFICIENT TECHNOLOGY REBATE

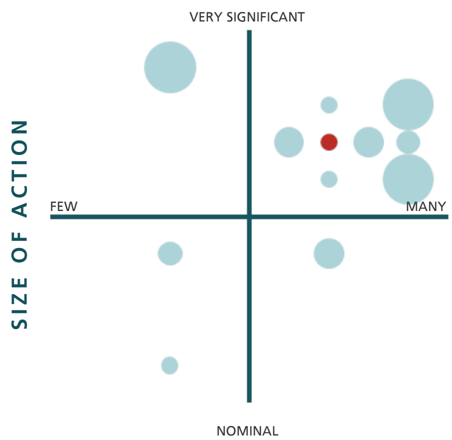
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 1-2 years
Realization: 5-7 years
Size of Impact: 0.1-1 Mcm

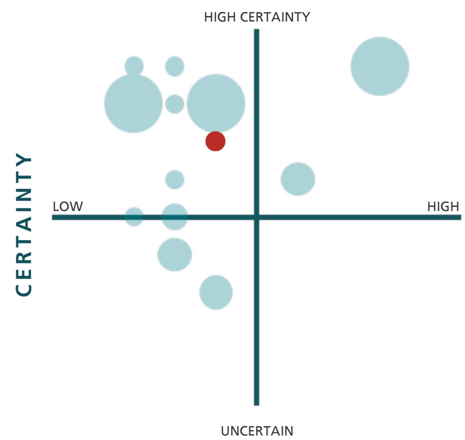
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 2-3 agencies (UPC, ADTA, EAA)
Size of Action: Significant
Size of Impact: 0.1-1 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

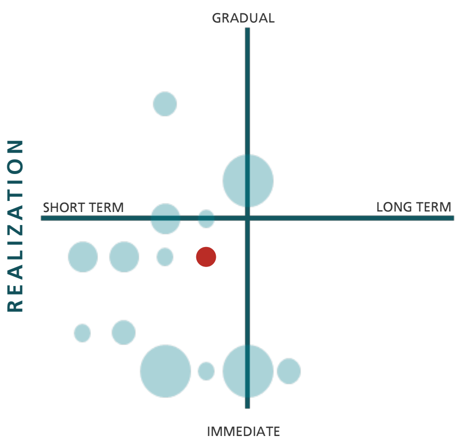
Cost to Government: 25-50 million Dh
Certainty: Average certainty
Size of Impact: 0.1-1 Mcm

In an effort to keep the tourism industry motivated to comply with the new hotel Pearl rating system, we recommend that Abu Dhabi provide financial incentives for hotels and resorts that install water-efficient devices. This would be used in addition to any subsidies awarded. This strategy will spur innovation and attract investment in the technology sector and encourage a competitive market for contractors to find the best technologies available. This will heighten visitor interest in traveling to the Emirate to see significant technological advances in water conservation. The perception of Abu Dhabi as a place that is deeply concerned about water while at the same time committed to maintaining the quality and beauty of the city could make it an even more desirable tourist destination.

This strategy has been implemented by the Las Vegas Southern Nevada Water Authority (SNWA) and has proven successful.[183] They offer rebates on several projects including (but not limited to) high efficiency toilet retrofits, waterless and high-efficiency urinal retrofits, cooling towers with high-efficiency drift elimination technologies, and automatic water saving device controls. Consumptive use-technologies (e.g., technologies that would reclaim or minimize outdoor water-use or water that is not returned to the sanitary sewer) earn 91.84 Dh per 3,785 liters ($25 per 1,000 gallons) of water that is saved annually, and non-consumptive use-technologies (e.g., technologies that would reclaim or minimize indoor water-use or water that is returned to the sanitary sewer) earn 29.39 Dh per 3,785 liters ($8 per 1,000 gallons) of water that is saved annually. The following conditions apply for all rebates: 1) projects must be maintained for at least ten years, 2) one proprietor can pool savings across multiple properties, and 3) a minimum water savings of 945,000 liters (250,000 gallons) per business must be actualized to qualify. Since 2001, businesses participating in this program have saved more than 6.615 billion liters (1.75 billion gallons) of water.

STRATEGY 1.3: CREATE A XERISCAPE CONVERSION REBATE

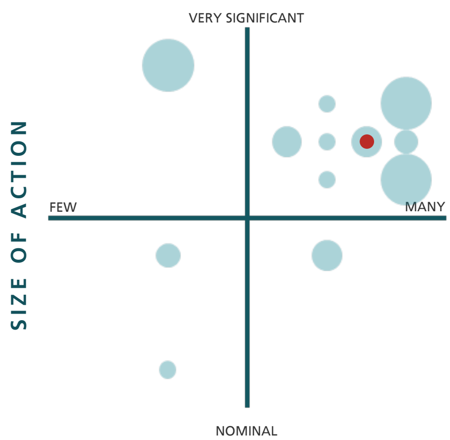
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 1-2 years
Realization: 3-5 years
Size of Impact: 0.1-1 Mcm

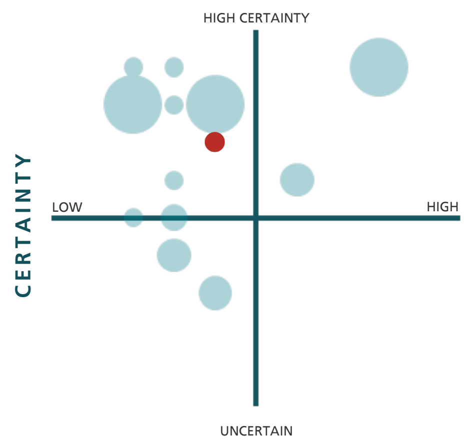
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 2-3 agencies (UPC, ADTA, EAA)
Size of Action: Significant
Size of Impact: 0.1-1 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 25-50 million Dh
Certainty: Average certainty
Size of Impact: 0.1-1 Mcm

We suggest that Abu Dhabi develop xeriscape conversion rebates for hotels, another incentive that has been applied by the SNWA[184] awards hotel and resort owners for transitioning to less water-intensive landscapes. This is important for conserving outdoor water in arid climates and saves a considerable amount of water. A rebate of up to 7.35 Dh ($27.00) per 0.093 square meter[185] can be awarded to businesses to convert to desert landscaping: 5.51 Dh ($1.50) per square meter for the first 465 square meters per site per year and an additional 3.67 ($1.00) Dh per square meter would be charged beyond the first 465 square meters for a maximum rebate amount of 1.1 million Dh per business.

There are some costs and considerations to be taken into account when taking advantage of this rebate such as project design fees, removal fees for existing landscape elements and their proper disposal (e.g., not composted or disposed of near lakes, rivers, or streams), project installation costs, and recycling used turf in green roofs or greenhouses. However, there are several benefits, which include lower water bills, reduced repair costs for water damage to sprinklers and damaged turf, lower landscape maintenance fees, and reduced pests and pest control costs.

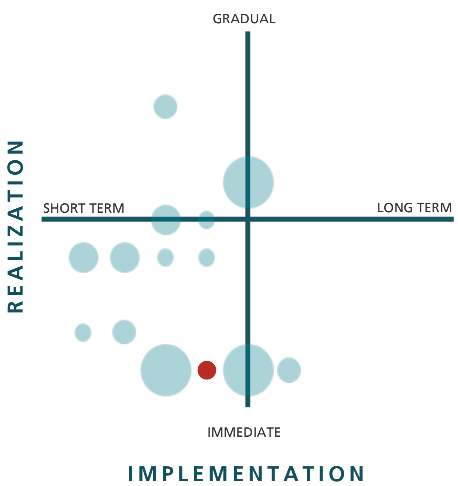
Landscape rebates can be quite lucrative and have been quite effective in Las Vegas. Every 0.093 square meter (1 ft^2) of grass that is replaced with water-smart trees, shrubs, and flowers saves an average of 207.9 liters (55 gallons) of water per year, which is a savings of 3.12 million liters (825,000 gallons) for every 1,395 square meters (15,000 ft^2) of water smart landscaping. It has proved especially successful, for golf courses. Las Vegas removed 1.9 million square meters (472 acres),[186] an equivalent of five 18-hole courses worth of turf, which is roughly 4.2 billion liters of water saved annually. Total landscape conservation efforts have saved Southern Nevada 68 billion liters (18 billion gallons) of water annually from 2002 to 2006. This was a 20% reduction during a period when nearly 330,000 more residents moved in and 40 million tourists visited.

RECOMMENDATION 2: INCREASE WATER EFFICIENCY IN HOTELS

Beyond ensuring the set of incentives that give major players in the hotel industry the ability to reduce their water consumption, efficiency for all hotels, can be improved whether pearl rated or not. We offer three strategies for improving water efficiency in the tourism sector: first, a mandate that hotels build decentralized greywater systems; second, the development of a linen exchange program; and third, facilitating the sharing of employee best practices.

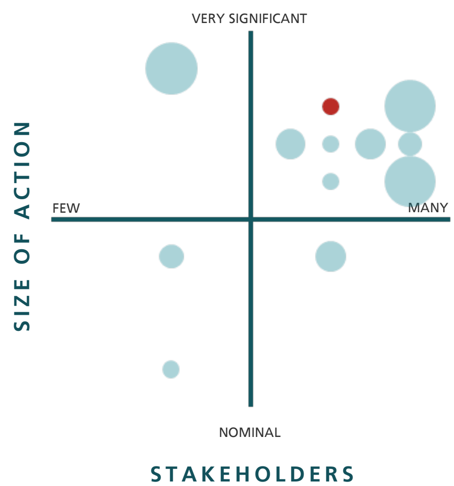
STRATEGY 2.1: MANDATE GREYWATER SYSTEMS IN HOTELS

TIMING OF IMPACT



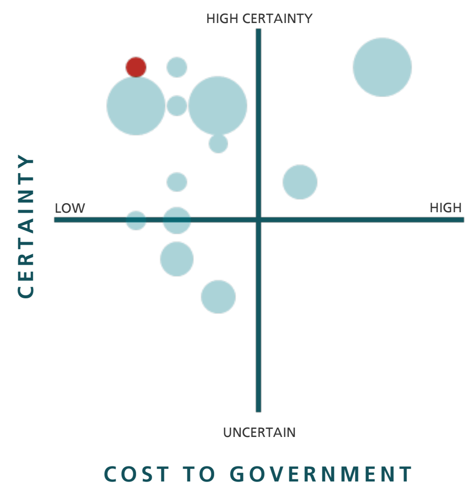
Implementation: 3-5 years
Realization: 0-1 years
Size of Impact: 0.1-1 Mcm

STAKEHOLDERS & SIZE OF ACTION



Stakeholders: Multiple firms
(UPC, ADTA, EAA, hotel owners)
Size of Action: Significant
Size of Impact: 0.1-1 Mcm

COST & CERTAINTY



Cost to Government: 1-10 million Dh
Certainty: Very high certainty
Size of Impact: 0.1-1 Mcm

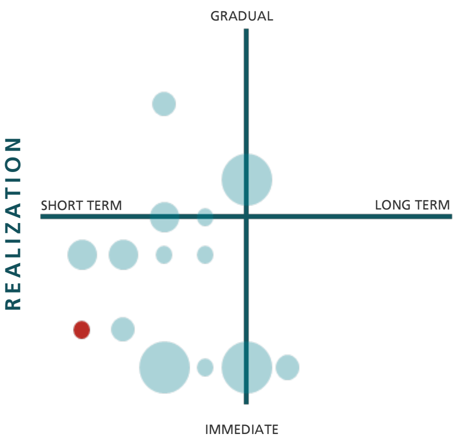
In conjunction with government regulation of the Hotel Pearl Rating System, we believe that Abu Dhabi should consider mandating that all Abu Dhabi hotels must either install greywater systems or retrofit existing plumbing for greywater reuse. Greywater would consist of any water used in the hotel, except water from toilets. While there have been no formal studies of the amount of greywater produced by a hotel, anecdotal figures have sink, dish, and laundry water typically comprising 50-80% of "waste" water. Greywater can be used for landscape irrigation and toilet flushing, thus saving the potable water equivalent that would have been used for that purpose. Large water savings can be captured by requiring that all existing hotels retrofit and future hotels construct greywater systems. Compliance with this regulation would need to be met in order to attain a Tourism License.

The impact on water savings from greywater system installations in Abu Dhabi hotels is dependent on the timing of when the Hotel Pearl Rating System is mandated into Abu Dhabi law and put into effect. In addition, the installation of greywater systems would vary according to whether it is a retrofit or part of new construction. Therefore, we estimate an average time of three to five years for such systems to be in place, with immediate water savings once the systems are in use.

We can extrapolate the potential impact from the limited studies of the impact of greywater systems in hotels. One study of an indoor greywater recycling system to flush the toilets in a hotel in Mallorca Island, Spain; (a 3-star hotel with 81 rooms) found that an average amount of water of 5,200 liters/day was re-used, which represented 23% of the total water consumption of the hotel.[187] A conservative baseline estimate of the water savings for Abu Dhabi would be approximately 213,200 liters per day. This figure would increase based on the number of rooms per hotel. In addition the Mallorca Island, Spain report found that hotel guests were pleased with the operation of the system and that their stay was not impacted by the use of greywater. Thus buy-in from the customer base should increase the likelihood of success given the hotel industry's primary concern of customer satisfaction.

STRATEGY 2.2: LINEN EXCHANGE PROGRAM

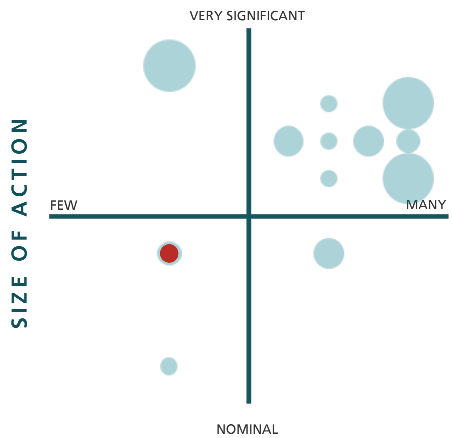
TIMING OF IMPACT



IMPLEMENTATION

Implementation: 0-1 years
Realization: 1-2 years
Size of Impact: 0.1-1 Mcm

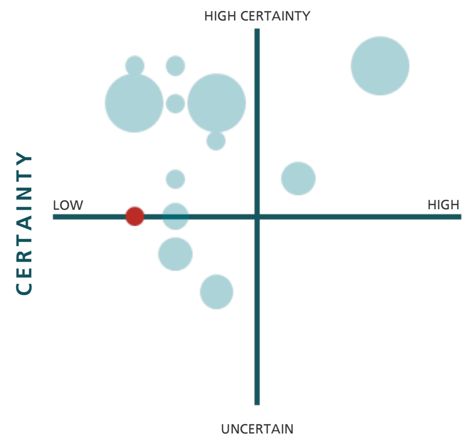
STAKEHOLDERS & SIZE OF ACTION



STAKEHOLDERS

Stakeholders: 41 hotel owners of Abu Dhabi
Size of Action: Modest
Size of Impact: 0.1-1 Mcm

COST & CERTAINTY



COST TO GOVERNMENT

Cost to Government: 1-10 million Dh
Certainty: Average certainty
Size of Impact: 0.1-1 Mcm

Another potential strategy to increase the efficiency of current water use is to change linens and towels only once per three days during a guest's stay. This program targets linens and towels and will reduce water usage on laundry per each guest room. It reduces costs associated with cleaning or sending laundry outside of the hotel as well as overall water use in the housekeeping department. This strategy has also been employed by the SNWA to great success. Similar strategies of those in Las Vegas have the potential to reduce operating costs by as much as 3.67 Dh per occupied room per day and as much as 30% less in laundry costs and increase average savings of washing linens and towels is 189 liters (50 gallons) per room per day.[18=]

Efforts to educate guests and make them aware of the importance of such practices will need to be communicated and encouraged. Studies have shown that in order to get guest cooperation, it is best that the hotel leaves cards in the room which convey not only an environmental message but also telling them that the previous guests also reused their towels. It is also best to tell guests that the hotel has already donated to an environmental organization rather than the hotel intends to donate if they reuse. Reuse increased in one case up to 45% knowing that the hotel had already donated.

Other Potential Strategies for Increasing Hotel Water Efficiency

In addition to the aforementioned strategies, we have highlighted practices used in a July 2002 study of two Seattle hotels sponsored by the Seattle Public Utilities (SPU). These strategies offer potential near-term, low-cost, and high-return tactics toward reducing water consumption.

1. **REDUCE OR DISCONTINUE "TRIPLE SHEETING"[190]**
   Triple sheeting is when three sheets are used per bed, which increases laundry loads.

   Potential Savings: Approximately 2 gallons (7.57 liters) of water per sheet. Additional savings would be available for labor (both laundry and housekeeping), energy (both for heating water and drying), and laundry chemicals
   Potential Cost: No cost/cost reduction
   Payback Period: Immediate

2. **REDUCE TOILET FLUSHES DURING ROOM CLEANING[191]**
   Toilets are typically flushed during cleaning – once prior to application of cleaning materials and once after. However, there typically is no need to flush prior to application.

   Potential Savings: Approximately 3,000 average gallons (approximately 11,356 liters) per day (based on the Seattle case study)
   Potential Cost: None
   Payback Period: Immediate

3. **EDUCATE KITCHEN STAFF REGARDING WATER CONSERVATION[192]**
   Excessive water use was observed in hotel kitchens for thawing food, washing rice, dishwasher loading, and equipment cleaning in the Seattle case study. The kitchen staff would need to be educated regarding proper techniques of the above practices.

   Potential Savings: Approximately 2,500 average gallons (approximately 9,463 liters) per day based on the case study)
   Potential Cost: Minimal
   Payback Period: Immediate

SUPPLY-SIDE RECOMMENDATIONS

INTRODUCTION

In addition to demand-side management, an effective long-term water plan for the Abu Dhabi Emirate will include supply-side management strategies. While supply shortages could be supplemented entirely through increased production of desalinated water, current desalination technologies have high energy requirements as well as environmental costs associated with brine disposal. Thus, in developing supply-side strategies, we believe that Abu Dhabi should move toward more sustainable methods of desalination. Further, there is potential for augmenting water supply through the development of young technologies. However, focused research is necessary in order to quantify the potential impact of alternative water technologies. In addition to increasing water capacity through desalination and alternative water technologies, there is high potential for growth in the supply sector through water reuse. A comprehensive supply-side management plan must include strategies for the use of treated sewage effluent (TSE).

The following provides a brief overview of several technologies to augment the Abu Dhabi water supply network. Although the proposed strategies are not representative of the universe of available technologies, they are representative of the three key components of a holistic supply plan: sustainable desalination, alternative water production, and water reuse.

SEAWATER
MICROBIAL DESALINATION CELLS

In an innovative and cutting-edge application of microbial fuel cell technology, researchers at Tsinghua University in Beijing, China, and Penn State University in Pennsylvania, US, are exploring using microorganisms to simultaneously perform three productive processes within one system: treat wastewater, desalinate water, and internally generate enough electricity to power these biochemical processes without external power inputs.

This is done by positioning an anode in one side chamber and a cathode in the other side chamber with a third chamber in between. The two side chambers are separated from the middle chamber with an anion exchange membrane or a cation exchange membrane depending on the type of adjacent chamber. Using wastewater as the source water, bacteria located on the anode & cathode process the organic material in the wastewater. This biochemical process generates an electric current, which causes the salt ions in the middle chamber to migrate through the membranes to the two side chambers depending on the ions' charge. This osmosis process results in desalinated water in the middle chamber while the bacterial processes result in treated wastewater in the side chambers.

Microbial desalination cell technology has currently reached proof-of-concept stage, with a small microbial desalination cell demonstrated to produce 2 W/m^2 (31W/m^3) and remove 90% of salt within a single desalination cycle.[193] The process was found to be effective with solutions containing salt concentrations as high as 35 g/L, which can be compared to electrodialysis processes which are recommended to be used only for solutions with up to 6 g/L in dissolved solids.[194]

Further research needs to be conducted in order to progress pass the proof-of-concept stage and allow the scale up of the technology. Additionally, since the test cells were conducted in a purely theoretical setting with simulated materials (e.g. artificial wastewater and continuous replenishment of electrode chamber water in relation to desalination chamber water), the process is far from reaching the practical application stage, much less economic viability. However, if commercialization of the technology is achievable, microbial desalination cells may provide a game-changing sustainable supply strategy for simultaneously treating wastewater and desalinating seawater.

Further reading

Cao, Xiaoxin, Xia Huang, Peng Liang, Kang Xiao, Yingjun Zhou, Xiaoyuan Zhang, and Bruce Logan, "A New Method for Water Desalination Using Microbial Desalination Cells," *Environ. Sci. Technol.* 43 (2009): 7148-7152.

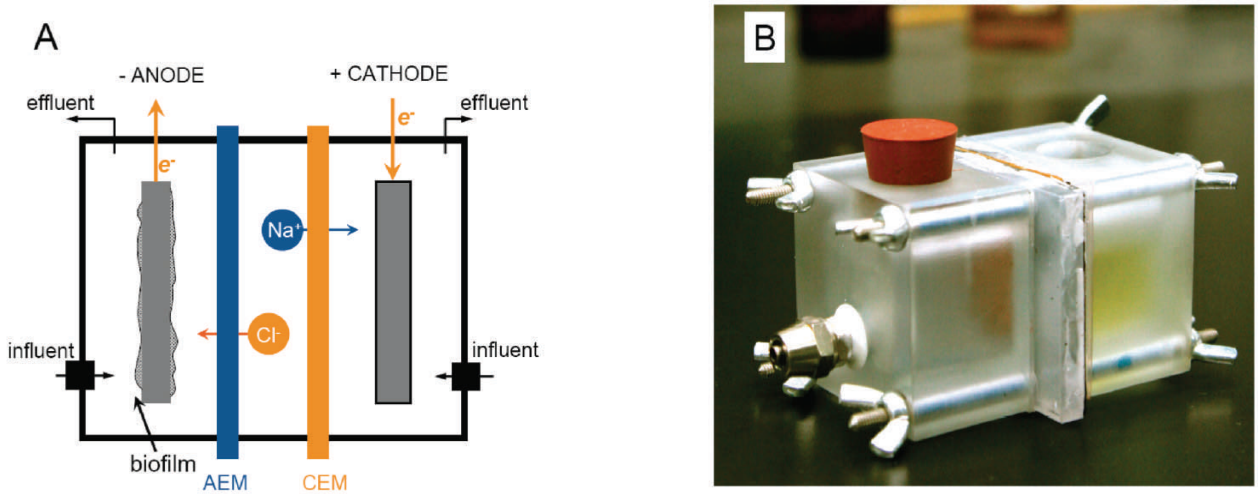
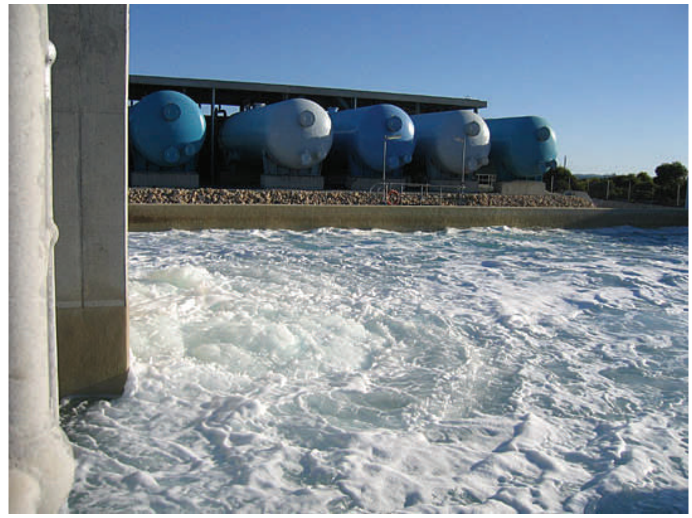


Figure 6. A three-chamber microbial desalination cell; (A) is a schematic diagram of the process, (B) is a photograph of the experimental test-sized cell. (Cao et al., 2009)

SEAWATER
TSE DESALINATION

Currently, more than a third (51 Mcm/yr) of the treated sewage effluent (TSE) produced in Abu Dhabi is disposed of into the Arabian Gulf due to capacity limitations of the current TSE irrigation distribution network.[218] Instead of disposing this substantial amount of usable water into the Gulf, this TSE surplus can be put to productive use and reused for many industrial uses, including within the power generation, electronics, cooling systems, and construction industries.[195]



Madwar and Tarazi conducted a feasibility study in 2002 evaluating the economic potential for 10,000 m^3/d wastewater RO desalination plants in the UAE. Their study demonstrated a cost advantage of wastewater desalination compared to seawater desalination due to the relatively low salt content of the wastewater. Desalination costs for wastewater were estimated to be 1.73 Dh/m^3, compared to 3.89 Dh/m^3 for seawater desalination.

Additionally, in 2007, the industrial sector, not including agriculture, used 46 Mcm of potable desalinated water for industrial applications.[196] This entire amount of industrial water demand may therefore be supplied by constructing a TSE desalination plant and building the distribution network extensions necessary to transport desalinated TSE to the industrial sector. Further, recovering the surplus TSE currently being disposed into the Gulf for productive industrial reuse will conserve potable desalinated water production, allowing more to be supplied for consumption purposes.

Further reading

Madwar, Karim, and Hani Tarazi, "Desalination techniques for industrial wastewater reuse," *Desalination* 152 (2002): 325-332.

SEAWATER
COMMERCIAL BRINE USE

Brine discharge into the Arabian Gulf from MSF desalination plants along the Abu Dhabi coast currently presents the greatest environmental challenge for using desalination technology as a sustainable source of water. More specifically, the elevated concentrations of chemicals within the brine as well as its higher temperature pose the main causes of the brine's negative environmental impact on the Gulf.[197] Both of these characteristics alter the current marine biological environment within the Gulf and may have potentially irreversible effects on its marine ecosystems.

The desalination process, which extracts fresh water from the seawater source, results in an effluent composed of higher concentrations of naturally occurring compounds within the original seawater as well as tangible concentrations of other potentially toxic chemicals added during the desalination process.[198] Researchers have found that brine discharge can contain salt concentrations of two or more times than that of the original feed water as well as elevated concentrations of compounds including chlorides, sulfates, copper, nickel, iron, and other anti-fouling and anti-scaling additives.[199] These compounds may also have deleterious effects upon the Gulf's marine biological organisms and may also bioaccumulate within the ecosystem.

Therefore, removing these substances from the desalination effluent will greatly improve the environmental impacts of seawater desalination on the Gulf. In addition, many of these chemicals possess monetary value and can potentially generate additional revenue for desalination plant operators from their extraction and sale on the commercial market for industrial use.[200]

Several methods for extraction of compounds from the brine discharge have been explored including solar, membrane, or thermal technologies, akin to standard desalination processes.[201] Specific applications of these methods include: evaporation ponds to completely eliminate water from the discharge, leaving chemical compounds in solid form; nano- and ultra-filtration membranes to physically separate chemical compounds from the brine liquid; and vapor compression technology to boil off brine liquid, resulting in extremely high grade purity chemical compounds.[202]

A study of RO desalination plants in Oman operated by Petroleum Development Oman, lists potential products from the brine discharge and their relevant market price, including magnesium hydroxide (807 Dh/t), sodium chloride (141 Dh/t), precipitated calcium carbonate (601-1424 Dh/t), sodium sulphate (343-404 Dh/t), and calcium chloride (USD $444/t).[203]

Given that virtually all of the potable water in Abu Dhabi, 1,044 Mcm in 2007[204], is provided by desalination plants, the commercial potential of extracting products from the brine discharge is quite substantial. In addition, due to the extremely high evaporation rate of the region, 2,000 mm/yr[205], and the open availability of desert lands, evaporation ponds to isolate chemical compounds are an ideal solution for handling brine dis-

Further reading

Ahmed, Mushtaque, Aro Arakel, David Hoey, Muralee R. Thumarukudy, Mattheus F.A. Goosen, Mansour Al-Haddabi, and Abdullah Al-Belushi, "Feasibility of salt production from inland RO desalination plant reject brine: a case study," *Desalination* 158 (2003): 109-117.

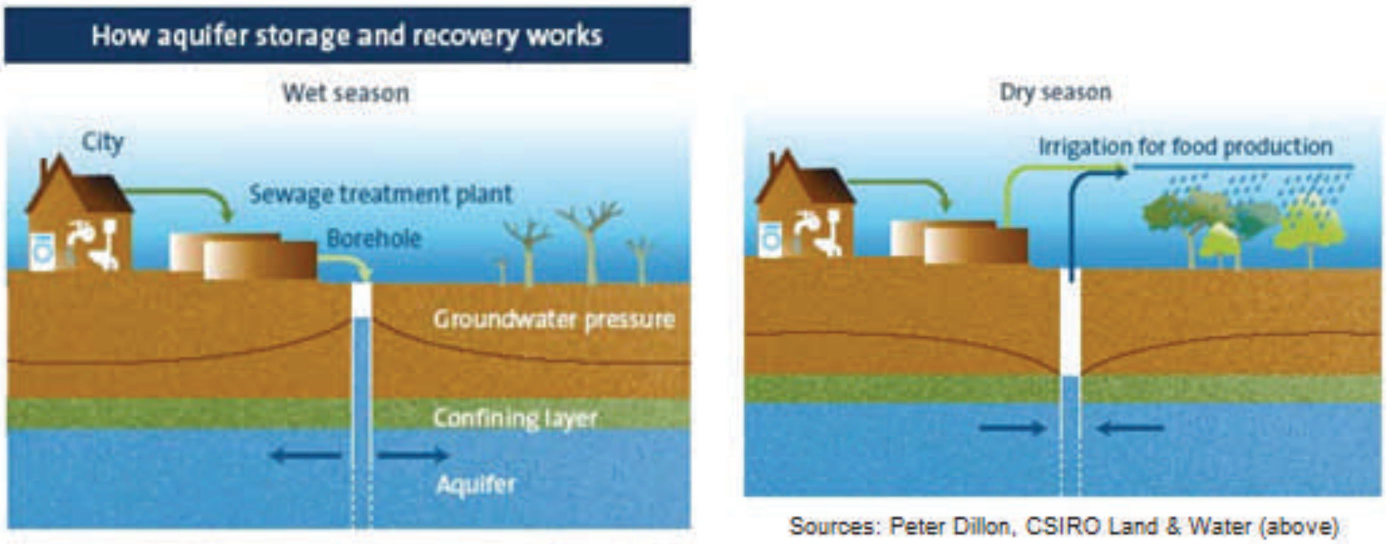
Ahmed, Mushtaque, Walid H. Shayya, David Hoey, Arun Mahendran, Richard Morris, and Juma Al-Handaly, "Use of evaporation ponds for brine disposal in desalination plants." *Desalination* 130 (2000): 155-168.

Alberti, Federica, Nicola Mosto, and Corrado Sommariva, "Salt production from brine of desalination plant discharge." *Desalination and Water Treatment* 10 (2009): 128-133.

Mohamed, A.M.O., M. Maraqa, and J. Al Handhaly, "Impact of land disposal of reject brine from desalination plants on soil and groundwater." Desalination 182 (2005): 411-433.

Sommariva, C., H. Hogg, and K. Callister, "Environmental impact of seawater desalination: relations between improvement in efficiency and environmental impact," *Desalination* 167 (2004): 439-444.

GROUNDWATER
RECHARGING DEPLETED AQUIFERS



Sources: Peter Dillon, CSIRO Land & Water (above)

Over extraction of groundwater reserves in Abu Dhabi has resulted in a 10 meter drop in the average water table level. When coupled with a low recharge rate, reservoirs are permanently dewatered or are being recharged with brackish or saline water. Artificial aquifer recharge is the intentional introduction of water to a groundwater aquifer via injection wells, spreading basins, dams, or in-stream projects. This strategy provides a secure method for strategic subsurface water storage with minimal surface installation.[206]

In Abu Dhabi, there is a high potential for aquifer recharge with excess desalinated water and treated sewage effluent (TSE). Currently, there is little to no storage capacity in the desalination transmission system – excess desalinated water is discharged into the gulf. Further, Abu Dhabi has storage capacity limitations for TSE. In Abu Dhabi, approximately 140 million liters day of TSE is discharged into the gulf. In Al Ain, comparable volumes of water are disposed of in the desert. Both excess desalinated water and TSE can be artificially injected into aquifers and later used to supplement the water supply in the Emirate and serve as a strategic water reserve for emergency supplies during seasonal peak demands.[207]

The storage and extraction capacity is dependent upon the site selected. One potential aquifer site in Abu Dhabi has storage capacity for 18.2 billion liters of water – this represents 20% of the 2007 total groundwater reserves.[208]

Aquifer storage and recovery provides substantial underground water storage with high recovery rates, significant cost savings when compared to surface water storage, reduced reliance on vulnerable, costly, surface water reservoirs, and enhanced water quality. Further, groundwater aquifer recharge operates with 88% efficiency. If implemented, considerations should be given to the potential physical and chemical interactions between the injected and native water.[209]

Artificial aquifer recharge is the focus of several pilot projects throughout the Middle East; however, it has not been deployed in the Middle East as a supply-side strategy. This strategy has been successfully employed in El Mezquital Valley, Mexico.

Further reading

Schlumberger Water Services. "Aquifer Storage and Recovery in Arid Environments: Abu Dhabi, United Arab Emirates," Schlumberger Water Services (July 1, 2007), http://www.slb.com/~/media/Files/water/case_studies/asr_abudhabi.ashx.

ATMOSPHERIC ENHANCED CONDENSATION

Enhanced condensation technologies have been developed as a means to augment water supply in arid environments.

Solar still enhanced condensation takes advantage of direct solar energy via the greenhouse effect to produce potable water. The process requires a black basin containing saline water, sealed tightly, and exposed to the sun. Solar energy heats the water resulting in evaporation. When the water vapor comes into contact with the cool glass ceiling, it condenses and is captured in a container. The results of several pilot projects indicate that the solar still is highly effective: seawater input with 35,000 ppm of totally dissolved solids (TDS) was converted into potable water with a TDS of 1–2 ppm. The simplest solar still is the single-basin type. But the yield of this still is in the range of 2–4 L/d per m^2 of still area, which is very limited. Daily yields of up to nine L/m^2 have been obtained at 35 degrees Celsius of ambient or approximately 1000 W/m^2 of insulation. For a given solar energy input, the factor limiting the distillate yield of solar still is inefficient condensation. The condensation rate can be increased either by lowering the wall temperature or increasing the area of the surface for condensation. Solar distillation projects have been implemented in regions throughout the world.[210]

Condensation irrigation is a combined system for solar desalination and irrigation and/or drinking water production. Solar stills are used for humidifying ambient air flowing over the saline water surface in the still. This warm, humid air is then led into an underground pipe system where it is cooled and vapor precipitates as freshwater on the pipe walls. Drinking water can be collected at the pipe endings. Commercial passive solar stills produce about 3–4 kg/m^2/d and are therefore mostly used for small-scale water production. Condensation irrigation has attracted attention from North African countries; pilot plants are in operation in Tunisia and Algeria.[211]

Atmospheric water harvesting or atmospheric water vapor processing (AWVP) is a technology that condenses and collects atmospheric water vapor. There are three methodologies employed:

- Water collection on cold surfaces using either heat pump technology or radiative cooling devices – water catchers for dew and fog have been constructed in Sweden, Tanzania, Tunisia, France, and Bahrain. The maximum daily fresh water yield was 11.4 L/m^2.

- Concentration of the vapor using desiccants – recent studies have successfully extracted water from air using a three stage process: absorption of humidity on a solid desiccant, adsorption of the water at moderate heat and condensation with a passive condenser connected to a heat pump.

- Inducing convection currents in a tall tower structure pushing the humid air to cold high altitude zone where condensation takes place – the first large application of this was built for the Grand Mosque.

AWVP produces high quality potable water; however, it is a relatively new technology for small-scale, locally managed water supplies.[212]

(Watercone, 2010)

ATMOSPHERIC FOG CAPTURE

(National Geographic Magazine via "Fog Catchers Bring Water to Remote Villages," Sincerely Sustainable, July 12, 2009)

Prevailing winds from the gulf bring hot and humid air to the coastal regions of the Abu Dhabi Emirate. Predominantly in the morning hours, this creates fog events along the coast. Fog capture is the collection of water from fog using fences and collectors. Fog contains about 0.05 grams of water per cubic meter.[213] Fog capture offers potential for water collection in Abu Dhabi.

The most rudimentary form of fog capture is through the construction of a fog fence (see picture). Fog is distributed by wind – when the wind flows through the mesh the fog condenses into droplets of water which flow downward and drip into a gutter; the water is then channeled through a sand filter and into a storage device. Fog fences constructed in Yemen retained 4.5 liters of water per square meter of mesh per day. In the Northern Province and West Coast of South Africa, maximum daily yields exceeded 3,800 liters.[214] In the Mediterranean Basin a more complex fog collector has been used. The fog collector was handmade, based on the Atmospheric Science Research Center of the State University of New York string collector. The device collects water from ocean fog and like the fog fence it requires minimal energy. First results showed that fog deposition might be comparable to precipitation amounts for a one-year period depending on location and exposure. During the summer period, when diurnal temperatures are high and rainfall amounts are small, fog collection was as much as 100 liters per square meter.[215]

The success of this strategy for Abu Dhabi depends upon fog occurrence, the persistence of fog episodes and the presence of fog bearing winds. In general, summer conditions in the Saadiyat and Abu Dhabi regions are ideal for fog capture. The respective water content of the air in these regions is 22 grams per kilogram and 18 grams per kilogram. Water content in these locations is high relative to Al Ain and Liwa, 13 grams per kilogram and 11 grams per kilogram respectively.[216]

Further reading

Estrela, Maria, José A. Valiente, David Corell, David Fuentes, "Fog Collection in a Region of the Western Mediterranean Basin: Evaluation of the use of Fog Water for the Restoration of Wildfire Burnt Areas," *Fundación CEAM*, (2009), http://portales.gva.es/ceam/ceamet/investigacion/publicaciones/FOG-2004.pdf.

ATMOSPHERIC RAINWATER HARVESTING

Water availability is a global matter of concern. Rainwater harvesting has a significant role to play in developing a solution. Rainwater harvesting is the collection and storage of rainwater from rooftops, land surfaces, or rock catchments. A rainwater collection system has three components: (1) a catchment system, (2) a conveyance system that transfers and sometimes filters collected water to a (3) collection device or storage container.[217]

- Rooftop catchment systems channel rainwater from a roof to a container for settling particulates before moving the water to a permanent storage container. This technique is most effective in areas that receive more than 200 mm of rainwater annually. Rooftop harvesting usually produces high quality water; however, to ensure continued quality storage containers must remain covered to prevent evaporative loss, contamination, and algae production. Further, rooftop materials affect collection capacity; therefore it is recommended that collection be set up with roofs made of galvanized corrugated iron, aluminum sheets, tiles and slates.[218]

- Ground catchment systems channel runoff water from a prepared catchment area into a storage device. A prepared catchment area is a land surface that has been modified to improve the runoff capacity by clearing or altering vegetative cover, increasing the land slope with artificial ground cover, reducing soil permeability by soil compaction and application of chemicals. An advantage of this system is that it allows for the opportunity to collect water from a larger surface area. Ground catchment systems are typically used in water scarce regions and have high potential catches.[219]

Rainwater harvesting techniques have been in practice for nearly two thousand years. This strategy requires no energy for operation, it has the potential to provide water to areas not connected to the municipal supply, and rainwater collection devices are simple and easy to install with little knowledge required for operation and maintenance. Rainwater harvesting is economically, socially, and environmentally responsible. However, potential water capacity is dependent on a highly variable resource; rainfall is unevenly distributed, limiting the application of this technology to small communities, households, and areas not connected to water supply lines. Further, although rainwater harvesting typically produces high quality catches of water, due to its proximity to the Gulf, rainwater in Abu Dhabi contains high levels of inorganic ions such as calcium, magnesium, sodium, potassium, and chlorine. Harvested water should be treated prior to consumption. A parabolic solar cooker or solar-water disinfection systems provide low-cost options for the treatment of stored rainwater in Abu Dhabi.[220]

Rainwater harvesting has been successfully implemented in regions throughout the world. A 2008 case study in Jordan produced yields that successfully augmented supply in urban areas for all twelve governorates.[221]

Further reading

For more information on this study, refer to *Roof Rainwater Harvesting Systems for Household Water Supply in Jordan*, Fayez A. Abdulla, A.W. Al-Shareef.

For additional information on rainwater harvesting technologies, please refer to:

Gould, J.E. 1992. Rainwater Catchment Systems for Household Water Supply, Environmental Sanitation Reviews, No. 32, ENSIC, Asian Institute of Technology, Bangkok.

Pacey, A. and A. Cullis 1989. Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas, WBC Print Ltd., London.

UNEP [United Nations Environment Programme] 1982. Rain and Stormwater Harvesting in Rural Areas, Tycooly International Publishing Ltd., Dublin.

CONCLUSION

For a government such as Abu Dhabi, filling their water shortfall represents more opportunity than challenge—a position unique among the water scarce countries of the Middle East. Many countries do not enjoy the political, social, and economic infrastructure needed to effectively address freshwater scarcity. Abu Dhabi has the technical and financial capacity to overcome the constraints of their extremely low renewable freshwater resources, yet numerous challenges remain.

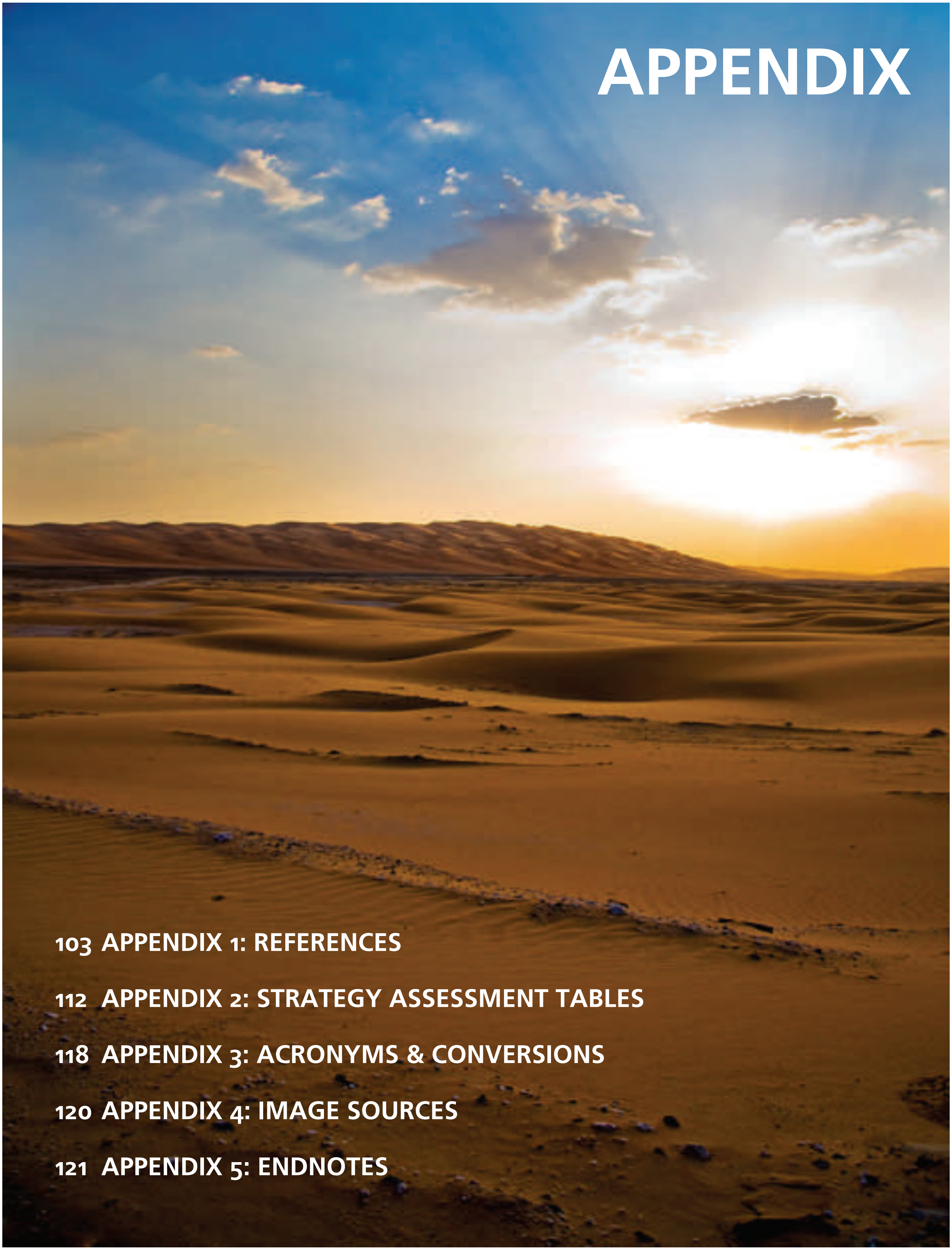
Perhaps the most important challenge facing Abu Dhabi is the low economic, environmental, and social value the Emirate's people, guests, and entities place on water. Over-consumption, which we assess applies the greatest pressure on Abu Dhabi's water resources, is a function of water's low value. This value has been shaped by the prevailing political, economic and social structures within the Emirate. These structures that have created Abu Dhabi's explosive short-term growth have also played an important role in perpetuating a model of unsustainability. Desalination plants have proliferated throughout the UAE, viewed as simple solutions to overcoming freshwater scarcity. But as we have shown, desalination comes with high costs, capital and environmental, and does little to address the root driver that is over-consumption—desalination merely enables it, feeding and dehydrating the Emirate's growth. The Emirate, therefore, sits at an imperative decision point: how will Abu Dhabi continue to develop, and at what costs?

We believe that sustainability is both the basis and goal of how Abu Dhabi could develop; growth does not need to come at the sacrifice of future generations, and in fact, sustainable growth can help the Emirate realize a lasting place among world economic leaders. Sustainability efforts can become a driver of new growth in of themselves, endowing Abu Dhabi's people with the resources and capacity to realize their human potential.

But to achieve this, we believe the focus of sustainability efforts for water supply should not rest only with technological solutions, but also with the more challenging solution of focusing on reducing water demand through a policy suite focusing on four of the most water-intensive sectors: agricultural, residential, public, and tourism. Within each of these sectors, there are numerous policy levers for effecting changes in water demand and an evaluation of these policies is the substance of this report.

Further, we highlighted four strategic cornerstones for any water sustainability efforts in Abu Dhabi, each of which aims to mitigate what we believe are the drivers of over-consumption. These cornerstones include the need for a cogent institutional framework for water management across all Abu Dhabi's government agencies, a coordinated data management and communication system for water supply and consumption, household-level water monitoring and metering within the water distribution network, and the mix of strategies designed to change the social, environmental, and economic value of water within the Emirate.

The effort to sustain Abu Dhabi's economic growth will be a decades-long challenge, but is well within the Emirate's reach. Abu Dhabi has the political leadership, institutional capacity, and economic infrastructure to provide a model for meaningful and sustainable change to desert landscapes the world over. We hope that it is an opportunity that the Emirate will seize.



APPENDIX

APPENDIX 1: REFERENCES

Abdulla, Fayez A. and A.W. Al-Shareef, "Roof rainwater harvesting systems for household water supply in Jordan," *ScienceDirect* 243 (2009).

Abidin, Ir Noor Azahari Zainal, "Operational Aspects of Water Demand Management," *Ministry of Energy, Green Technology and Water, Malaysia*. (2009), http://www.jba.gov.my/index.php/muat-turun/doc_download/78-operational-aspects-of-water-demand-management (accessed April 29, 2010).

Abu Dhabi Urban Planning Council, "Al Bateen Waterfront Design Guidelines," *Sustainable Urban Planning* (2010), http://www.upc.gov.ae/guidelines/al-bateen-waterfront-design-guidelines.aspx (accessed April 29, 2010).

Abu Dhabi Tourism Authority, "1st Quarter 2007-Hotel Statistics Summary by Hotel Classification," (2007), http://www.abudhabitourism.ae/en/info/first.quarter.aspx (accessed April 8, 2010).

Abu Dhabi Tourism Authority, "2nd Quarter 2007-Hotel Statistics Summary by Hotel Classification," (2007), http://www.abudhabitourism.ae/tacme/admin/content/file/2nd%20quarter%202007/22q07.pdf (accessed April 8, 2010).

Abu Dhabi Tourism Authority, "Abu Dhabi's MICE Potential Expanding, Says Expert," Abu Dhabi Tourism Authority, Press Release, (February 15, 2009), http://www.abudhabitourism.ae/en/news/tom.hulton.aspx (accessed April 8, 2010).

Abu Dhabi Tourism Authority, "About Abu Dhabi Tourism Authority (ADTA)," (2009), http://www.abudhabitourism.ae/en/main/about-adta.aspx (accessed April 8, 2010).

Abu Dhabi Tourism Authority, "Vision, Mission, Values & Quality Policy," (2009) http://www.abudhabitourism.ae/en/main/vision.mission.and.values.aspx (accessed April 8, 2010).

Academy for Educational Development, "From Crisis to Consensus: A New Course for Water Efficiency in Jordan," AED Center for Environmental Strategies, (No Date), www.aed.org/Publications/upload/crisis_to_consensus.pdf (accessed April 29, 2010).

AED Academy for Educational Development, "Water Efficiency and Public Information for Action (WEPIA) Program, 2000-2005 Final Report," *United States Agency for International Development and The Academy for Educational Development* (2005), http://jordan.usaid.gov/upload/keydocs/WEPIA%20Final%20Report.pdf (accessed April 29, 2010).

AED Center for Environmental Strategies. "From CRISIS to CONSENSUS: *A New Course for* Water Efficiency *in* JORDAN," (No Date) www.aed.org/Publications/upload/crisis_to_consensus.pdf. (accessed April 29, 2010).

Ahmed, Mushtaque, Aro Arakel, David Hoey, Muralee R. Thumarukudy, Mattheus

F.A. Goosen, Mansour Al-Haddabi, and Abdullah Al-Belushi. "Feasibility of salt production from inland RO desalination plant reject brine: a case study." *Desalination* 158 (2003): 109-117.

Ahmed, Mushtaque, Walid Shayya, David Hoey, Arun Mahendran, Richard Morris, and Juma Al-Handaly. "Use of evaporation ponds for brine disposal in desalination plants." *Desalination* 130 (2000): 155-168.

Akkad, Adnan, "Water conservation in Arabian Gulf countries," *Journal of the American Water Works Association* 82 (1990): 40-50.

Alameddine, M. El-Fadel, "Brine discharge from desalination plants: a modeling approach to an optimized outfall design." *Desalination* 214 (2007) 241–260.

Alberti, Federica, Nicola Mosto, and Corrado Sommariva. "Salt production from brine of desalination plant discharge." *Desalination and Water Treatment* 10 (2009): 128-133.

APPENDIX 1: REFERENCES

Al-Ghadban, A.N., F. Abdali, M.S. Massoud. "Sedimentation rate and bioturbation in the Arabian gulf." *Environment International*, Vol. 24, No. 1/2, (1998) pp. 23-31.

Al-Jayyousi, Odeh R., "Greywater Reuse: Towards Sustainable Water Management," *Desalination* 156 (2003): 181-192.

Al Serkal, Mariam M., "Sharjah to Introduce Power Saving System" *Gulf News,* (February 27, 2008) http://gulfnews.com/news/gulf/uae/environment/sharjah-to-introduce-power-saving-system-1.86682 (accessed April 29, 2010).

Al-Sodi, AM., "Attitudes of Jordanian Citizens Towards Environmental Protection in Sweileh and Naser Mountains Areas," *Environmental Research and Studies, Amman, Jordan Environment Society* 3 (1993).

Arabian Business, "Water Waste and Conservation," (2007), http://www.arabianbusiness.com/index.php?option=com_content&view=article&id=495859. (accessed April 8, 2010).

Arnold, Thomas Clay. 2008. The San Luis Valley and the Moral Economy of Water. Chap. 2 in *Water, Place, and Equity*, edited by John M. Whitely, Helen Ingram, and Richard Warren Perry. Cambridge, Mass.: MIT Press, 39.

Atallah, S., Ali Khan, M.Z., Malkawi, M., "Water Conservation Through Islamic Public Awareness in the Eastern Mediterranean Region," *Eastern Mediterranean Health Journal* 5(1999): 785-797.

Attari, Shahzeen Z., Michael L. DeKay, Cliff I. Davidson, and Wändi Bruine de Bruin. "Public Perceptions of Energy Consumption and Savings," Columbia University (2010) unpublished.

Brewer, Peter G., D. Dyrssen, "Chemical oceanography of the Persian Gulf." Prog. Oceanog. Vol. 14 (1985): 41-55.

Brown, Chris, "Water Conservation in the Professional Car Wash Industry," International Carwash Association (2010), http://www.carwash.org/SiteCollectionDocuments/Research/Environmental%20Reports/Water%20Conservation%20in%20the%20Professional%20Car%20Wash%20Industry.pdf (accessed April 29, 2010).

Brown, Gary and Sabitha Sakkir. "The Vascular plants of Abu Dhabi Emirate," *Terrestrial Environment Research Center* (2004), http://www.ead.ae/TacSoft/FileManager/Publications/reports/TERC/plantchecklistv1_2.pdf (accessed April 29, 2010).

California Data Exchange Program, "Overview of CDEC," Department of Water Resources (2010), http://cdec.water.ca.gov/intro.html (accessed April 3, 2010).

Cao, Xiaoxin, Xia Huang, Peng Liang, Kang Xiao, Yingjun Zhou, Xiaoyuan Zhang, and Bruce Logan. "A New Method for Water Desalination Using Microbial Desalination Cells." *Environ. Sci. Technol.* 43 (2009): 7148-7152.

Casas, Joseph, Mahnoud Solh, and Hala Hafez, "NARS in the WANA Region: An Overview and Cross-Country Analysis," *WANA NARS Study*, (1999), http://www.icarda.org/NARS/WANA_Region.pdf (accessed April 29, 2010).

Central Ground Water Board,"Regional Data Centre," Central Ground Water Board, Ministry of Water Resources Government of India (No Date), http://cgwb.gov.in/ncr/rodc.htm (accessed April 1, 2010).

Cheng, Caleb, "Online Resources for Environmental Impact Analysis: California Data Exchange Center (CDEC)," Online Data Resources of California (1996), http://ice.ucdavis.edu/education/esp179/?q=node/70 (accessed April 3, 2010).

Chung, Jen, "City Unveils Green Campaign GreeNYC." *Gothamist* (June 26, 2007), http://gothamist.com/2007/06/26/city_unveils_gr.php (accessed April 29, 2010).

APPENDIX 1: REFERENCES

City of Santa Rosa, "Water Efficient Landscape Policy," (2007), http://www.downtownsr.org/doclib/Documents/updatedwaterefficientlandscapepolicy.pdf (accessed April 29, 2010).

Colorado Springs Utilities. "Xeriscape Demonstration Garden." (2010). http://www.csu.org/wa/xeri/xeriscape.jsp. (accessed April 18, 2010).

Conniff, Richard, "Using Peer Pressure as a Tool to Promote Greener Choices," *Yale Environment 360* (2009), http://e360.yale.edu/content/feature.msp?id=2141 (accessed April 29, 2010).

The Corporate Social Responsibility Newswire, "Harvesting Energy –Going Green! New York Marriott Downtown is First Hotel in New York City to Install Energy-Efficient Tri-generation Plant," (June 5, 2008), http://www.csrwire.com/press/press_release/25245-Harvesting-Energy-Going-Green-New-York-Marriott-Downtown-is-First-Hotel-in-New-York-City-to-Install-Energy-Efficient-Tri-generation-Plant- (accessed April 8, 2010).

Crase, Lin, Dollery, Brian, Byrnes, Joel, " An Intersectoral Comparison of Australian Water Reforms," *Water Policy* 10 (2008): 43–56.

Crosbie, Ewan, "Understanding and Management of Atmospheric Water." (presentation, Rowan Williams Davies & Irwin Inc. (RWDI), Abu Dhabi, UAE, March 17, 2010).

Dawoud, Mohammed A., "Strategic Water Reserve: New Approach for Old Concept in GCC Countries," *Environment Agency Abu Dhabi*, (2008).

Department of Water Resources, "California Data Exchange Center," Department of Water Hydrological Data, (2010), http://www.water.ca.gov/floodmgmt/docs/CDEC_Brochure.pdf (accessed April 29, 2010).

Dubai Electric and Water Authority, "Tariff Details," Government of Dubai (2010), http://www.dewa.gov.ae/tariff/tariffdetails.aspx (accessed April 29, 2010).

Eastern Municipal Water District, "EMWD's Water Wise Demonstration Garden 2270 Trumble Road, Perris," (2009), http://www.emwd.org/conservation/demo-garden.html#1 (accessed April 29, 2010).

El-Naser, Nazim K., *Management of Scarce Water Resources: A Middle Eastern Experience.* Southampton: WIT Press, (2009).

Energy Information Association (EIA). "International Energy Outlook 2009." May 2009. 30 July 2009 http://www.eia.doe.gov/oiaf/ieo/world.html

Environment Agency – Abu Dhabi (EAD), *Water Resources of Abu Dhabi Emirate, United Arab Emirates* (Abu Dhabi: Environment Agency – Abu Dhabi, 2006), 10.

Environment Agency – Abu Dhabi (EAD), *AbuDhabi Water Resource Master Plan*, (2009).

Estrela, Maria, José A. Valiente, David Corell, David Fuentes, "Fog Collection in a Region of the Western Mediterranean Basin: Evaluation of the use of Fog Water for the Restoration of Wildfire Burnt Areas," *Fundación CEAM*, (2009), http://portales.gva.es/ceam/ceamet/investigacion/publicaciones/FOG-2004.pdf.

Euro-Mediterranean Information System on know-how in the Water Sector, "Jordan: National Water Strategy 2008-2022 Adopted," EMWIS, (2009), http://www.emwis.net/countries/fol749974/country045975/national_program/thematicdirs/news/jordan-jd586b-water-strategy-finalized (accessed April 1, 2010).

APPENDIX 1: REFERENCES

Executive Affairs Authority Abu Dhabi, "Economic Affairs," (No Date), http://eaa.abudhabi.ae/Sites/EAA/Navigation/EN/AdvisoryUnits/economic-affairs,did=122220,render=renderPrint.html (accessed April 10, 2010).

Fadlelmawla, A., "Towards Sustainable Water Policy in Kuwait: Reforms of the Current Practices and the Required Investments, Institutional and Legislative Measures," *Water Resources Management*, 23 (2009): 1969-1987.

Fernandez-Lopez, C., A. Viedma, R. Herrero, and A.S. Kaiser. "Seawater integrated desalination plant without brine discharge and powered by renewable energy systems." *Desalination.* 235(2009): 179-198.

Flatt, Victor, "Act Locally, Affect Globally: How the structure of Local government makes it the Best Arena for Engagement and Work with the private Sector to control Environmental Harms," UNC Chapel Hill School of Law and University of Houston Law Center, (2007), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1002664 (accessed April 29, 2010).

Fleming ,Sibley, "Doubling Down on Green." *Green Building Survey of Developers.* (November 13, 2009). http://nreionline.com/green-building/commercial-real-estate-on-green/

Forstmeier, Markus, Fredrik Mannerheim, Fernando D'Amato, Minesh Shah, Yan Liu, Michael Baldea, and Albert Stella. "Feasibility study on wind-powered desalination." *Desalination.* 203(2007): 463-470.

Gara, Tom, "Facts show Twitter yet to lure Middle East users." *The National.* (July 20, 2009)http://www.thenational.ae/apps/pbcs.dll/article?AID=/20090720/BUSINESS/707209936/0/FOREIGN(accessed April 15, 2010).

Garcia-Rodriguez, Lourdes. "Renewable energy applications in desalination: state of the art." *Solar Energy* 75(2003): 381-393.

Geller, E. Scott, Jeff Erickson and Brenda Buttram, "Attempts to Promote Residential Water Conservation with Educational, Behavioral and Engineering Strategies," *Population and Environment,* 6 no. 2, (Summer 1983): 96-112.

Ghareeb, Edmund, "New Media and the Information Revolution in the Arab World: An Assessment," *Middle East Journal* 54, (2000): 395-418.

Gray, B.M.,"Fighting crime through education and advertising," *Public Relations Review* 8 (1982): 45-50.

GreeNYC, "Anti-Idling Campaign," (2009), http://www.drivingsustainability.com/files/NYC_Bloomberg_AntiIdling%20Report_December%202009.pdf (accessed April 29, 2010).

Habeebullah, Badr. "Potential Use of Evaporator Coils for Water Extraction in Hot and Humid Areas," *Desalination*, 237 (2009).

Hamdane, Abdelkader, "Tunisia: Reform of Irrigation Policy and Water Conservation – Case #19," Global Water Partnership Toolbox: Integrated Water Resource Management (2008), http://www.gwptoolbox.org/images/stories/cases/en/cs%2019%20tunisia.pdf (accessed April 29, 2010).

Heal, G.M. Valuing ecosystem services. *Working Paper: Columbia Business School*. (January 1999), 8.

Hill, Ginny, "Comic answer to Yemen water crisis," *BBC News,* (September 4, 2008), http://news.bbc.co.uk/2/hi/middle_east/7595552.stm (accessed April 29, 2010).

Iannotti, Marie, "Xeriscape Gardening: Planning for a Water Wise Garden; A Common Sense Approach to 'What Plant Where?,'" About.com Guide http://gardening.about.com/od/gardendesign/a/Xeriscaping.htm (accessed April 29, 2010).

International Center for Biosaline Agriculture (ICBA), "Biosaline," (2010), http://www.biosaline.org/. (accessed March 30, 2010).

APPENDIX 1: REFERENCES

Internet World Stats, "United Arab Emirates- Internet Usage and Marketing Report," (2009), http://www.internetworldstats.com/me/ae.htm (accessed April 29, 2010).

Jones, Tom, "Pricing Water," *OECD Observer* 236, (2003) http://www.oecdobserver.org/news/fullstory.php/aid/939/Pricing_water.html (accessed April 29, 2010).

Jordan Ministry of Water and Irrigation, "About MWI," Ministry of Water and Irrigation (2009), http://www.mwi.gov.jo/english/mwi/Pages/default.aspx (accessed April 1, 2010).

Jordan Ministry of Water and Irrigation, "National Water Master Plan (NWMP)," Ministry of Water and Irrigation, http://www.mwi.gov.jo/english/mwi/NationalPlan/Pages/default.aspx (accessed April 1, 2010).

Kaufman, Leslie, "Utilities Turn Their Customers Green, With Envy, " *New York Times*, (January 30, 2009), http://www.nytimes.com/2009/01/31/science/earth/31compete.html?_r=1 (accessed April 20, 2010).

Kalogirou, Soteris A. "Seawater desalination using renewable energy sources." *Progress in Energy and Combustion Science* 31(2005): 242-281.

Khanna, Raman, "Abu Dhabi Hotel Plan Current and Future," Aldar Hotels & Hospitality (2007), http://www.b-e-x.com/downloads/Raman%20Khanna,%20Aldar.pdf, (accessed April 8, 2010).

King, Robert N., "Identifying Effective and Efficient Methods To Educate Farmers about Soil Sampling," *Journal of Extension* 37, no. 1 (1999), http://www.joe.org/joe/1999february/rb3.php (accessed April 20, 2010).

Kirat, Mohamed, "Promoting online media relations: Public relations departments' use of Internet in the UAE," *Public Relations Review* 33, no. 2 (2007): 166-74 http://vnweb.hwwilsonweb.com.ezproxy.cul.columbia.edu/hww/results/external_link_maincontentframe.jhtml?_AARGS=/hww/results/results_common.jhtml.42 (accessed April 29, 2010).

Krakovsky, Marina, "Hotel Case Study: Peer Pressure's Impact on the Environment," *Scientific American.* (November 2008). http://www.scientificamerican.com/article.cfm?id=hotel-case-study. ("accessed" April 8, 2010).

Kumar, Vinoth and Kasturi Bai, "Performance Study on Solar Still with Enhanced Condensation," *Desalination*, 203 (2008): 51-61.

Kuttschreuter, Margot and Oene Wiegman, "Crime Prevention and the Attitude Toward the Criminal Justice System: The Effects of a Multimedia Campaign," *Journal of Criminal Justice* 26 (1997): 441-452.

Landais, Emmanuelle, "Dubai Introduces New Rates to Curb Use of Electricity and Water, " *Gulf News,* (February 17, 2008), http://gulfnews.com/news/gulf/uae/general/dubai-introduces-new-rates-to-curb-use-of-electricity-and-water-1.85172 (accessed April 29, 2010).

Lindblom, Jenny and Bo Nordell, "Water Production by Underground Condensation of Humid Air," *Desalination* 198 (2006).

Lucid, Nancy, "Hardscape," Santa Clara University, (2005), http://www.scu.edu/stclaregarden/sustainable/hardscape.cfm (accessed April 29, 2010).

Lumpa, Kuala. "Muslim washing rite goes hi-tech with "wudu" machine," *Reuters*. (January 31, 2010), http://www.reuters.com/article/idUSTRE6100FM20100201, (accessed at March 24, 2010).

Lurigio, Arthur J. and Dennis P. Rosenbaum, "The effects of mass media on crime prevention awareness, attitudes, and behavior: The case of crime stoppers," *American Journal of Criminal Justice.* 15, no. 2 (1991), <http://www.springerlink.com.ezproxy.cul.columbia.edu/content/b658r6q774kn7524/fulltext.pdf>. (accessed April 29, 2010).

APPENDIX 1: REFERENCES

Madani, Ismail, "Islam and Environment," For Environmental Awareness in the Gulf Countries, Manama, Bahrain, Ministry of Information (1989): 123-131 (in Arabic).

Madwar, Karim, and Hani Tarazi. "Desalination techniques for industrial wastewater reuse." *Desalination* 152 (2002): 325-332.

March, J.G., M. Gual and O. Orozco, "Experiences on greywater re-use for toilet flushing in a hotel (Mallorca Island, Spain)," *Desalination* 164, no. 3, (2004): 241-47.

Midden, Cees, Joanne Meter, Mieneke Weenig, and Henk Zieverink, "Using Feedback, Reinforcement and Information to Reduce Energy Consumption in Households: A Field-Experiment," *Journal of Economics Psychology* 3 (1983): 65-68.

Mohamed, A.M.O., M. Maraqa, and J. Al Handhaly. "Impact of land disposal of reject brine from desalination plants on soil and groundwater." *Desalination* 182 (2005): 411-433.

Montano, John, phone interview by Jill Kano, February, 23, 2010, New York Marriott Downtown, New York, New York.

National Media Council, "UAE Yearbook 2009," (2009) http://www.uaeinteract.com/uaeint_misc/pdf_2009/data/engl_yearbk_09.pdf. (accessed April 1, 2010).

National Public Radio, "Stakes High for Las Vegas Water Czar," (2010) http://www.npr.org/templates/story/story.php?storyId=10939792, ("accessed" April 8, 2010).

NationMaster. "Time Series> Media> Radio receivers> United Arab Emirates," (2010), http://www.nationmaster.com/time.php?stat=med_rad_rec&country=tc. (accessed April 8, 2010).

The Nature Conservancy, "Car Washing and the Environment," (2010) http://www.nature.org/wherewework/northamerica/states/indiana/misc/art22036.html, (accessed April 10, 2010).

North Carolina Department of Environment and Natural Resources. "Hotel/Motel Waste Reduction." Reference Collection. http://www.p2pays.org/ref/01/00421.pdf (accessed April 8, 2010).

Ofwat, "International comparison of water and sewerage service 2007 report," 2007, http://www.ofwat.gov.uk/regulating/reporting/rpt_int2007.pdf (accessed April 1, 2010).

O'Keefe, Garrett J., "The McGruff national media campaign: Its public impact and future implications," In D.P. Rosenbaum (Ed.), *Community Crime Prevention: Does it work?* Beverly Hills: Sage. (1986)

O'Keefe, Garrett J., Dennis P. Rosenbaum, Paul J. Lavrakas, Kathaleen Reid, and Renee A. Botta, "'Taking a Bite Out of Crime': the Impact of the National Citizens' Crime Prevention Media Campaign," Thousand Oaks, CA: Sage Publications, (1996).

O'Neill & Siegelbaum and The RICE Group, "Hotel Water Conservation: A Seattle Demonstration," (July 2002) http://www.corecentre.co.in/Database/Docs/DocFiles/hotel_water.pdf. (accessed April 8, 2010).

Olivier, J and C.J. de Rautenbach, "The implementation of fog water collection systems in South Africa," *Atmospheric Research*, 64 (2002): 227-38.

Pallack, Michael S., David A. Cook, and John J. Sullivan, "Commitment and Energy Conservation," In *Applied Social Psychology Annual*, Vol. 1, ed. L. Bickman, (Beverly Hills: Sage Publications, (1980) 235-53.

APPENDIX 1: REFERENCES

Petersen, John E, Vladislav Shunturov, Kathryn Janda, Gavin Platt and Kate Weinberger, "Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives," *International Journal of Sustainability in Higher Education,* 8 No. 1, (2007), 16-33.

Research Department of the Caribbean Tourism Organization, "Hotel Classification System Summary of articles and Information on Hotel Classification System," (2002) http://www.onecaribbean.org/content/files/hotelcalssification(1).pdf. (accessed April 8, 2010).

Research and Markets, "United Arab Emirates - Telecoms, Mobile and Broadband." (2009), http://www.researchandmarkets.com/reports/1081229/united_arab_emirates_telecoms_mobile_and.htm, (accessed April 8, 2010).

Reynolds, R.M., "Physical oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman – results from the Mt. Mitchell expedition", *Marine Pollution Bulletin* 27 (1993) 35–59.

Roudi-Fahimi, Farzaneh, et al., "Finding the Balance; Population and Water Scarcity in the Middle East and North Africa," Population Reference Bureau (2002) http://www.prb.org/Publications/PolicyBriefs/FindingtheBalancePopulationandWaterScarcityintheMiddleEastandNorthAfrica, (accessed March 28, 2010).

Schlumberger Water Services. "Aquifer Storage and Recovery in Arid Environments: Abu Dhabi, United Arab Emirates," Schlumberger Water Services (July 1, 2007), http://www.slb.com/~/media/Files/water/case_studies/asr_abudhabi.ashx.

Sendhil Mullainathan and Richard H. Thaler, "Behavioral Economics," Massachusetts Institute of Technology Department of Economics Working Paper Series, Working Paper (2000) 00-27.

Semiat, Raphael. "Energy Issues in Desalination Processes." *Environmental Science & Technology* 42 (2008): 8193-8201.

Sethi, S., Walker, S., Drewes, J., Xu, P. "Existing and emerging concentrate minimization & disposal practices for membrane systems." *Florida Water Resources Journal* (2006):40,42,44,46,48.

Sheppard, Charles, Mohsen Al-Husiani, F. Al-Jamali, Faiza Al-Yamani, Rob Baldwin, James Bishop, Francesca Benzoni, Eric Dutrieux, Nicholas K. Dulvy, Subba Rao V. Durvasula, David A. Jones, Ron Loughland, David Medio, M. Nithyanandan, Graham M. Pilling, Igor Polikarpov, Andrew R.G. Price, Sam Purkis, Bernhard Riegl, Maria Saburova, Kaveh Samimi Namin, Oliver Taylor, Simon Wilson, Khadija Zainal. "The Gulf: A young sea in decline." *Marine Pollution Bulletin 60* (2010): 13–38.

Smith, Ronald, Anton Purnama, H.H. Al-Barwani. "Sensitivity of hypersaline Arabian Gulf to seawater desalination plants." *Applied Mathematical Modeling* 31 (2007) 2347–2354.

Sommariva, C., H. Hogg, and K. Callister, "Environmental impact of seawater desalination: relations between improvement in efficiency and environmental impact." *Desalination* 167 (2004): 439-444.

Southern Nevada Water Authority, "Water Efficient Technologies," (2010). http://www.snwa.com/html/cons_wet.html. (accessed April 8, 2010).

Southern Nevada Water Authority, "Water Smart Landscapes Rebate," (2010). http://www.snwa.com/html/cons_wsl.html (accessed April 8, 2010).

Southern Nevada Water Authority, "Linen Exchange Program," (2010). http://www.snwa.com/html/cons_biz_linen.html. (accessed April 8, 2010).

Srinivas, Hari, "An Introduction to Rainwater Harvesting," *The Global Development Research Center*, http://www.gdrc.org/uem/water/rainwater/introduction.html, (accessed April 10, 2010).

APPENDIX 1: REFERENCES

Stenekes, Nyree, Hal Colebatch, David T. Waite, and Nick Ashbolt, "Risk and Governance in Water recycling: Public Acceptance Revisited," *Science Technology and Human Values.* 31, no. 2, (2006): 107-134.

Sustainable Sources, "Xeriscape," (2010). http://xeriscape.sustainablesources.com/ (accessed April 18, 2010).

Taebi , Amir and Ronald Droste, "Pollution Loads in Urban Runoff and Sanitary Wastewater," *Science of the Total Environment*, (2004): 327.

Taha, Suzan and Philipp Magiera, *National Water Master Plan*, Amman: Ministry of Water and Irrigation. http://www.mwi.gov.jo/Arabic/MWI/NationalPlan/Documents/nwmp%20brochure.pdf.

Thaler, Richard H. and Cass R. Sunstein, "Nudge: improving decisions about health, wealth, and happiness." New York: Penguin, (2009).

Todorova, Vesela,"Abu Dhabi's water conservation plans." *The National*. (May 18, 2008). http://www.thenational.ae/article/20080518/NATIONAL/970674321. (accessed April 10, 2010).

Tonner, John. *Desalination and Water Purification Research and Development Program Report No. 144: Barriers to Thermal Desalination in the United States.* Virginia: National Technical Information Service Operations Division, (2008).

UAE Census Higher Authority. "Census 2005," http://www.tedad.ae/english/statistic/economic_activity.html. (accessed April 29, 2010).

UAE Government, "Medial and Information." http://www.uae.gov.ae/Government/media.htm. (accessed April 29, 2010).

UAE Interact, "Municipality of Abu Dhabi City Approves Landscaping Layouts of 4 Major Intersections," (2010), http://www.uaeinteract.com/docs/Municipality_of_Abu_Dhabi_City_approves_landscaping_layouts_of_4_major_intersections/40334.htm, (accessed April 29, 2010).

United States Central Intelligence Agency, "The World Fact Book: United Arab Emirates,"(2010) CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/ae.html, (accessed April 10, 2010).

VanDerZanden, Ann Marie, "Hardscapes for Sustainable Landscapes," Oregon State University Extension Service (2003), http://extension.oregonstate.edu/catalog/pdf/ec/ec1535.pdf. (accessed April 10, 2010).

Warren, Stuart and Ted Bilderback. "Irrigation Timing: Effect on Plant Growth, Photosynthesis, Water-Use Efficiency and Substrate Temperature," *Acta Hort.*, (2004):644, http://www.ces.ncsu.edu/depts/hort/nursery/research/reference-publications/Warren-Bilderback-irrig-timing.pdf . (accessed April 19, 2010).

Water Information, "Information Sheet 3- The Australian Water Resources Information System," Australian Government Bureau of Meteorology. http://www.bom.gov.au/water/about/publications/document/InfoSheet_3.pdf (accessed April 1, 2010).

Water Information System Data Online Management, "About WISDOM." Central Water Commission India. http://www.india-water.com/index.asp (accessed April 1, 2010).

World Resources Institute, Actual Renewable Water Resources, 2007

Wheeler, Stephen M. and Timothy Beatley, *The Sustainable Urban Development Reader,* London: Routledge, (2004).

Whyte, Patrick, "Australia knows something about drought" *Los Angeles Times,* (January 4, 2009). Online edition. http://www.latimes.com/news/printedition/asection/la-oe-whyte4-2009jan04,0,270396.story. (accessed April 1, 2010).

Wicks, Robert, "Understanding audiences: learning to use the media constructively," New Jersey: Lawrence Erlbaum Associates, (2000).

APPENDIX 1: REFERENCES

Winkler, Robin C. and Richard A. Winett, "Behavioral Interventions in Resource Conservation," *American Psychologist*, (1982): 420-435.

The World Health Organization, "WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume 2 Wastewater use in agriculture" World Health Organization, (2008)

Xeriscape Council of New Mexico. Water Conservation and Xeriscaping Conference http://www.xeriscapenm.com/, (accessed April 18, 2010).

Zawya Ltd., "Rising demand-supply gap brings GCC water policy in the spotlight," http://www.zawya.com/Story.cfm/sidZAWYA20091222043601/Rising%20demand-supply%20gap%20brings%20GCC%20water%20policy%20in%20the%20spotlight, (accessed April 10, 2010).

APPENDIX 2: STRATEGY ASSESSMENT TABLES

Size of Impact:

In million cubic meters per year

Strategy	Assumption	Notes
Residential		
Raise public awareness		
Create a mass media campaign	5-10 Mcm	Similar campaigns have often seen between 3%-10% reductions in consumption.
Use influential public figures	5-10 Mcm	Similar campaigns have often seen between 3%-10% reductions in consumption.
Increase water conservation incentives		
Give clear reduction strategies	50-70 Mcm	Depending on and in concert with the awareness efforts, reduction strategies could enable the populous toward a goal of 250 liters per day.
Give clear feedback	20-30 Mcm	Until everyone uses less water (which is achieved through other strategies), comparisons to neighbors, etc., will make less of an impact.
Change the value of water	+100 Mcm	Assuming a drop to 250 liters per day, population of 1.75 million people
Public Realm		
Convert public landscapes		
Use xeriscaping	+100 Mcm	Amenity uses 366 Mcm of desalinated water and 51 Mcm of groundwater per year. By replacing green areas with xeriscaping and hardscaping, we see a potential 25% reduction in water use. This is a very conservative estimate given the results of other regions (see California case study).
Increase landscaping	+100 Mcm	Amenity uses 366 Mcm of desalinated water and 51 Mcm of groundwater per year. By replacing green areas with xeriscaping and hardscaping, we see a potential 25% reduction in water use. This is a very conservative estimate given the results of other regions (see California case study).
Make fountains sustainable	0.1-1 Mcm	There are thousands of fountains in Abu Dhabi, even a modest reduction may lead to significant conservation rates.
Create Sustainable Landscape Manual	1-5 Mcm	The impact would be seen compared against business as usual (avoiding water-intensive landscapes), and may not make substantial direct reductions, however, implementing the designs will have a significant impact.
Improve public space irrigation efficiency		
Irrigation scheduling	01.-1 Mcm	The impact would be small, almost solely due to water savings from reduced evapotranspiration.
Use more greywater for irrigation	1-5 Mcm	The size of the impact is dependent upon the amount of greywater that is reused for irrigation.
Agriculture		
Improve agricultural inefficiency		
Establish innovation and extension centers	5-10 Mcm (Desalinated) +100 Mcm (Groundwater)	A 10% in decrease in water use from both groundwater and desalinated water would equal roughly 116.6 Mcm/year and 7.6 Mcm/year, respectively.
Establish Standards for Alternative Water Sources	5-10 Mcm	Reductions from this strategy could potentially use 5-10 Mcm of wasted water.
Tourism		
Generate water conservation incentives		
Create and incorporate a hotel Pearl Rating System	0.1-1 Mcm	Roughly 0.643 Mcm per year reduction
Water efficient technologies rebate	0.1-1 Mcm	945,000 minimum L saved per year * 41 business owners = 0.038 Mcm per year.
Xeriscape conversion rebate	0.1-1 Mcm	A 20% conversion rate would yield between 0.1 - 1 Mcm per year, given the experience in Las Vegas.
Increase water efficiency in hotels		
Install greywater systems	0.1-1 Mcm	5.2 cubic meters saved per day per room * 6774 rooms in Abu Dhabi * 365 days per year = 0.158 Mcm per year.
Linen exchange program	0.1-1 Mcm	0.0189 cubic meters saved per day per room * 6774 rooms in Abu Dhabi * 365 days per year = 0.081 Mcm.

APPENDIX 2: STRATEGY ASSESSMENT TABLES

Implementation spectrum: Immediate to gradual (in years)		Realization spectrum: Immediate to gradual (in years) - Noncumulative	
Assumption	Notes	Assumption	Notes
0-1 years	The campaign could launch as soon as it is designed.	3-5 years	Though the public may react immediately, deep shifts in awareness may not occur for a few years.
1-2 years	Workshops and training curriculum are already in the beginning stages, they would need to be expanded.	3-5 years	Developing the curriculum and training to educate public figures may take a few years before significant conservation is realized.
1-2 years	Reduction strategies could be released as soon as researched and designed.	1-2 years	Clear processes would be most effective with short-term goals.
1-2 years	Once metering and billing systems are in place, feedback could be given with a billing cycle.	3-5 years	Since comparisons are drawn on previous year's usage and relative conservation, the system must be in place for a few cycles before impact is realized.
5-7 years	Pricing could happen as soon as sufficient metering is in place, however, public reception will need to be cultivated over at least 5 years to generate support / acceptance and to result in change.	0-1 years	Almost immediate, depending upon level of price.
5-7 years	Conversion from current landscaping to xeriscaping and hardscaping will likely take over 5 years until there is a significant impact.	7-10 years	Individual conversions will take effect immediately, while a large scale realization of water conservation will take more time.
5-7 years	Conversion from current landscaping to xeriscaping and hardscaping will likely take over 5 years until there is a significant impact.	7-10 years	Individual conversions will take effect immediately, while a large scale realization of water conservation will take more time.
3-5 years	Transforming or replacing all fountains will likely take a few years to plan and enact all of the changes.	0-1 years	The impact of the changes will be immediate.
2-3 years	The UPC could meet with developers over 1 year and takes up to 3 years to create guidelines.	13-16 years	As designs for new developments and improvements go to the UPC for approval, the sustainable landscape policies must be followed. Therefore, it may take significant time before all landscapes are overhauled.
1-5 years	Creating the policies, means to enforcement, and enacting them may take 1-5 years depending upon the priority of the initiative.	3-5 years	There should be little lag between when the policy is put in place and when the results are seen and there may be some lag from a learning curve, but little else.
7-10 years	Creating these systems would take a while to fully incorporate into a complete water network.	0-1 years	Immediate impacts, but dependent upon the construction of the systems.
2-3 years	From planning to opening, the centers can be erected within 2-3 years of government approval.	5-7 years	Farmers would have to be trained and similar studies have shown results around 5-7 years after implementation.
1-2 years	Creating standards will need scientific study and interagency coordination, but it can be done in 1-2 years.	3-5 years	Results from establishing standards may take more time as infrastructure is developed and as farmers adopt the new techniques.
2-3 years	To develop and launch the system would likely take a 2-3 years.	3-5 years	Once the system is in place, realization would like phase in over the coming 3-5 years.
1-2 years	Economists and the UPC would need to set the optimal rebate, create the regulation and financing, and then make sure the appropriate stakeholders were aware.	5-7 years	Depending on the rebate levels, hotels may take years to replace old technologies
1-2 years	Economists and the UPC would need to set the optimal rebate, create the regulation and financing, and then make sure the appropriate stakeholders were aware.	3-5 years	Depending on the rebate levels, hotels may take years to convert current landscapes, however these may be quicker fixes than technology changes.
3-5 years	It may take a 3-5 years for hotels to comply with the standard of installing graywater systems.	0-1 years	Once the systems are installed, the realization should be immediate.
0-1 years	The UPC / ADTA can begin running workshops and create guidelines immediately.	1-2 years	There may be a few months of lag between training and the realization of water conservation.

APPENDIX 2: STRATEGY ASSESSMENT TABLES

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In million cubic meters per year

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Give clear feedback	20-30 Mcm	Until everyone uses less water (which is achieved through other strategies), comparisons to neighbors, etc., will make less of an impact.
Change the value of water	+100 Mcm	Assuming a drop to 250 liters per day, population of 1.75 million people
Public Realm		
Convert public landscapes		
Use xeriscaping	+100 Mcm	Amenity uses 366 Mcm of desalinated water and 51 Mcm of groundwater per year. By replacing green areas with xeriscaping and hardscaping, we see a potential 25% reduction in water use. This is a very conservative estimate given the results of other regions (see California case study).
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Make fountains sustainable	0.1-1 Mcm	There are thousands of fountains in Abu Dhabi, even a modest reduction may lead to significant conservation rates.
Create Sustainable Landscape Manual	1-5 Mcm	The impact would be seen compared against business as usual (avoiding water-intensive landscapes), and may not make substantial direct reductions, however, implementing the designs will have a significant impact.
Improve public space irrigation efficiency		
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Agriculture		
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Establish Standards for Alternative Water Sources	5-10 Mcm	Reductions from this strategy could potentially use 5-10 Mcm of wasted water.
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Water efficient technologies rebate	0.1-1 Mcm	945,000 minimum L saved per year * 41 business owners = 0.038 Mcm per year.
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APPENDIX 2: STRATEGY ASSESSMENT TABLES

Size of Stakeholder Involvement Estimated of number of parties (# of agencies or individuals)		Action spectrum Size of action required from stakeholders (Passive to Very Significant)	
Assumption	Notes	Assumption	Notes
2 to 3 agencies and a marketing group: (EAD / EAA / RSB, etc.)	-	Modest	The action would be small. Most agencies have 1-2 people working on such campaigns and contract out the rest to marketing groups.
The majority of public figures and religious leaders (appx. 3,000)	-	Significant	Public figures would need to agree with, be familiarized on, be willing to support and incorporate the conservation message; a modestly significant action.
All residents in Abu Dhabi	-	Significant	Residents would be asked to make substantial changes to their everyday routines.
All residents in Abu Dhabi	-	Modest	Residents would be asked to look at water statements, take them seriously, and act independently to make reductions.
All residents in Abu Dhabi	-	Significant	Residents may feel that they are being asked to do more because money will be leaving their accounts.
Roughly three agencies / stakeholders (DMA / EAD) and private contractors.	-	Very Significant	Designing, planning, and converting these realms would require a significant amount of labor, along with the strong political backing and messaging to ensure that the public understands the initiatives.
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Roughly three agencies / stakeholders (DMA / EAD) and developers.	-	Modest	Native plant lists exist for the region, so creating a manual and policy for developments would not require significant research. Additional work in design approval would be necessary.
Roughly three agencies / stakeholders (DMA / EAD) and developers.	-	Passive	Little would change for those affected by the policy aside from the timing of the watering.
Roughly three agencies / stakeholders (DMA / EAD) and developers.	-	Modest	Depending upon the involvement of the government to actually put these systems in place versus simply creating the policy.
The Ministry of Agriculture and Fishing along with universities.	-	Significant	The action is significant and the undertaking would require thoughtful planning and staffing, but it would not significantly alter the responsibilities of the government agencies and the universities.
Roughly three agencies / stakeholders (RSB, EAD, MAF)	-	Modest	This would take some collaboration between agenceis and would need some scientific research to determine the standards.
Multiple agencies (UPC / ADTA, etc.), developers, and hotel owners.	-	Significant	This action is significant, but much of the work is in crafting appropriate policies.
Multiple agencies (UPC / ADTA, EAA), developers, and hotel owners.	-	Significant	This action is significant because incorporating xeriscape conversion requires a sizeable amount of labor.
Multiple agencies (UPC / ADTA / EAA), developers, and hotel owners.	-	Significant	This action is significant because incorporating water efficient technologies requires a sizeable amount of labor.
Multiple agencies (UPC / ADTA, etc.), developers, and hotel owners.	-	Significant	There would be high labor and construction costs if the government mandated and finance such a proposal.
The 41 hotel owners of Abu Dhabi.	-	Modest	Hotels would simply need to train staff and inform customers, which is a modest action.

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APPENDIX 2: STRATEGY ASSESSMENT TABLES

Cost to Government:
Estimate of implementation costs (in Dirham)

Degree of Certainty:
Estimate of certainty of success (relative to other policies)

Assumption	Notes	Assumption	Notes
10-25 million	No more than 25 million dirham based on conversations with GreeNYC representatives.	Somewhat Uncertain	About 10% decrease of 550 = 35 Mcm based on 1.75 million
1-10 million	Workshops, training, educational materials and staffing would probably cost no more than 10 million dirham.	Somewhat Uncertain	3-% decrease of 550 = 10-20 Mcm, based on 1.75 million
10-25 million	This effort would require similar marketing and analysis to a mass media campaign or would happen in tandem with ongoing campaigns.	Average Certainty	Without penalties, not all participants will participate.
10-25 million	This would require less marketing than a mass media campaign, yet with higher data management and metering costs.	High Certainty	This strategy provides pointed interaction / feedback with consumer and there are many controlled studies that show impact is quite certain.
25-50 million	Enforcement and collection may cost roughly 25-50 million dirham per year.	High Certainty	Few incentives can drive behavior like money.
250-500 million	All xeriscaping, hardscaping, and fountain modifications would likely amount to between 250-500 million Dirham.	Very High Certainty	Results are proven, scientifically based, and a pilot study would help to illustrate this.
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250-500 million	All xeriscaping, hardscaping, and fountain modifications would likely amount to between 250-500 million Dirham.	Very High Certainty	Results are proven, scientifically based, and a pilot study would help to illustrate this.
1-10 million	Consulting with developers and using information from the EAD's native plant species list should be low cost.	High Certainty	As the organization approving new design, the UPC could enforce the new policies once established.
10-25 million	Would only require altering schedules for manual watering and reprogramming for automatic. There may be some costs associated with enforcement.	Very High Certainty	Results are proven, scientifically based, and a pilot study would help to illustrate this.
25-50 million	Depending upon the involvement of the government. If the government helps finance the systems, then probably a significant cost.	High Certainty	Once the systems are in place, they are a technical solution so there is little room for error.
100-250 million	Capital and staffing costs, along with ongoing operational costs will be high, though they can be offset by shifting current subsidies to the agriculture centers.	Average Certainty	Certainty is a function of the education the centers bring to agriculture and the ability of the centers to innovate. Results have been proven abroad, but the variables are still based on human behavior and initiative.
1-10 million	Research and development of the standards would not create many more costs than current budget requirements.	Somewhat Uncertain	Alternatives to groundwater have not been used much, there may be some public hesitancy, and the demand for alternative water from other users may decrease the viability its use for agriculture.
10-25 million	Costs are estimated based upon the example of the Seattle W-Hotel. System cost: 514,317 Dh, 79% subsidy percentage used from Exhibit 1 = total subsidy of 406,310 Dh per hotel: 79% * 514,317 Dh: * 41 hotels = Roughly 16 million Dh	Average Certainty	All of the passive measures (installation of lower water use technology) will be certain conservation techniques. Changing tourist behavior will be less certain.
25- 50 million	5.51 Dh per square meter for the first 465 square meters per site per year and an additional 3.67 Dh per square meter would be charged beyond the first 465 square meters for a maximum rebate amount of 1.1 million Dh per business * 41 hotels = 45.12 million.	Average Certainty	All of the passive measures (installation of lower water use technology) will be certain conservation techniques. Changing tourist behavior will be less certain.
25-50 million	A maximum rebate of 1.1 million Dh per business * 41 hotels = roughly 50 million Dh.	Average Certainty	All of the passive measures (installation of lower water use technology) will be certain conservation techniques. Changing tourist behavior will be less certain.
1-10 million	100,000 average rebate to each hotel *4 hotels = 4.1 million dirham	Very High Certainty	If implemented, the impacts would be all but certain.
1-10 million	If fully subsidized and at full occupancy, roughly 2.5 million dirham. (3.67 Dh / room * 6774 rooms *365 days)	Average Certainty	Results have been consistent in many locations, but this strategy is still dependent upon individual behavior.

APPENDIX 3: ACRONYMS & CONVERSIONS

ACRONYMS

ADDC	Abu Dhabi Distribution Company
ADSSC	Abu Dhabi Sewerage Services Company
ADTA	Abu Dhabi Tourism Authority
ADWEA	Abu Dhabi Water & Electricity Authority
ADWEC	Abu Dhabi Water and Electricity Company
AWRIS	Australian Water Resources Information System
C	Celsius
CDEC	California Data Exchange Center
CFL	Compact Fluorescent light bulbs
CI	Condensation Irrigation
CIA	US Central Intelligence Agency
DEWA	Dubai Electricity and Water Authority
Dh	Dirham
DMA	Department of Municipal Affairs
DSC	Data Storage Centers (India)
EAA	Executive Affairs Authority
EAD	Environment Agency of Abu Dhabi
EMI	Emirates Media, Inc.
GHG	Greenhouse Gas
GIS	Geographic Information Systems ArcView spatial databases
ICBA	International Center for Biosaline Agriculture
km^3	Kilometer cubed
L	Liter
m^2	Meter squared
Mcm	Million cubic meters
mg	Milligram
Mm^3	Million meters cubed
MDEC	Meter and Data Exchange Code
MED	Multi-effect distillation
MIST	Masdar Institute of Science and Technology
MSF	Multi-stage flash
MVC	Mechanical vapor compression

APPENDIX 3: ACRONYMS & CONVERSIONS

ACRONYMS

MWI	Ministry of Water and Irrigation (Jordan)
NWMP	National Water Master Plan (Jordan)
NYC	New York City
OECD	Organisation for Economic Co-operation and Development
PDO	Petroleum Development Oman
pH	Hydrogen potential, a measure of the alkalinity or acidity of a substance
ppm	Part per million
PSA	Public service announcement
PSU	Practical salinity unit
RO	Reverse osmosis
RO-ED	Reverse osmosis electro-dialysis
RSB	Regulation & Supervision Bureau
SNWA	Las Vegas (USA) Southern Nevada Water Authority
TDS	Total dissolved solids
TRANSCO	Abu Dhabi Transmission and Despatch Company
TSE	Treated sewage effluent
UAE	United Arab Emirates
UPC	Abu Dhabi Urban Planning Council
USA	United States of America
USGS	United States Geological Survey
WED	Water and Electricity Department of Abu Dhabi
WEPIA	Water Efficiency and Public Information for Action (Jordan)
WHO	World Health Organization
WIS	Water Information System (Jordan)
WISDOM	Water Information System Data Online Management (India)
yr	Year

CONVERSIONS

1 US Dollar = 3.67 UAE Dirham

APPENDIX 4: IMAGE SOURCES

Cover

http://www.thgholidays.co.uk/middle-east_abu-dhabi.phtml

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Christopher Hawkins

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http://www.flickr.com/photos/john_pattison_photography/4210258567/sizes/o/

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http://emwd.org/conservation/images/street-before.jpg

http://emwd.org/conservation/images/street-after.jpg

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Katie Wurden

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http://www.flickr.com/photos/denn/337143305/sizes/o/

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http://www.biosaline.org/images/Shadehouse.jpg

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Katie Wurden

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http://www.libertyparkusafd.org/lp/BuildingGreenUSA/Solar%20Power%20Desalination/Kwinana%20Desalination%20Plant%20-%20Perth,%20Australia.jpg

http://ocvoice.files.wordpress.com/2009/03/tampa-bay-florida-desalination-plant.jpg

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http://www.watercone.com/1600/work1600.jpg

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http://www.sincerelysustainable.com/water/fog-catchers-bring-water-to-remote-rural-villages

Page 102

http://www.flickr.com/photos/13082206@N08/2933849176/sizes/o/

APPENDIX 5: ENDNOTES

1. Arnold, Thomas Clay. 2008. The San Luis Valley and the Moral Economy of Water. Chap. 2 in *Water, Place, and Equity*, edited by John M. Whitely, Helen Ingram, and Richard Warren Perry. Cambridge, Mass.: MIT Press, 39.
2. Environmental Agency (EAD) *Abu Dhabi Water Resource Master Plan – Draft*, 2009: 28.
3. Ibid.
4. Ibid.
5. Ibid.
6. World Resources Institute, Actual Renewable Water Resources, 2007
7. Water Resources Master Plan, 2009.
8. Ofwat, "International comparison of water and sewerage service 2007 report," 2007, http://www.ofwat.gov.uk/regulating/reporting/rpt_int2007.pdf (accessed April 1, 2010).
9. Water Resources Master Plan, 2009.
10. Mohammed A. Dawoud, "Strategic Water Reserve: New Approach for Old Concept in GCC Countries," *Environment Agency Abu Dhabi*, 2008.
11. Water Resources Master Plan, 2009.
12. Water Resources Master Plan, 2009.
13. Water Resource Master Plan, 2009.
14. Water Resources Master Plan, 2009.
15. Heal, G.M. Valuing ecosystem services. *Working Paper: Columbia Business School*. (January 1999), 8.
16. Another source of environmental damage is from the water intake process, which can be a violent disturbance to contiguous marine communities. These impacts will be explored briefly below.
17. Tonner, John. *Desalination and Water Purification Research and Development Program Report No. 144: Barriers to Thermal Desalination in the United States.* Virginia: National Technical Information Service Operations Division, (2008).
18. The data for this calculation are cobbled together from several sources and as such, should be weighed with proper uncertainty. Kalogirou, Soteris A. "Seawater desalination using renewable energy sources." *Progress in Energy and Combustion Science* 31(2005): 242-281; Energy Information Association (EIA). "International Energy Outlook 2009." May 2009. 30 July 2009 http://www.eia.doe.gov/oiaf/ieo/world.html; National Research Council (NRC), *Review of the Desalination and Water Purification Technology Roadmap*, Washington, National Academies, 2008
19. NRC, 2008.
20. Semiat, Raphael. "Energy Issues in Desalination Processes." *Environmental Science & Technology* 42 (2008): 8193-8201.
21. Multi-stage flash is the dominant desalination process, accounting for more than 88% of desalination in the Gulf region. Abuzinada, H.-J. Barth, F. Krupp, B. Böer and T.Z. Al Abdessalaam, (eds.). Protecting the Gulf's Marine Ecosystems from Pollution, chapter "Impacts of seawater desalination plants on the marine environment of the Gulf" Sabine Lattemann and Thomas Höpner, 2008, 194.
22. Cogeneration is the use of byproduct heat in electricity generation to distill water. Lattemann and Höpner, 194; Buros, O.K. The ABCs of Desalting 2nd edition. International Desalination Association: Massachusetts, 2000; Semiat, 8194.
23. U.S. Environmental Protection Agency (EPA). "Acid Rain." 2008. <http://www.epa.gov/acidrain/>.
24. Ibid.
25. Garcia-Rodriguez, Lourdes. "Renewable energy applications in desalination: state of the art." *Solar Energy* 75(2003): 381-393.
26. Forstmeier, Markus, Fredrik Mannerheim, Fernando D'Amato, Minesh Shah, Yan Liu, Michael Baldea, and Albert Stella. "Feasibility study on wind-powered desalination." *Desalination.* 203(2007): 463-470.
27. Fernandez-Lopez, C., A. Viedma, R. Herrero, and A.S. Kaiser. "Seawater integrated desalination plant without brine discharge and powered by renewable energy systems." *Desalination.* 235(2009): 179-198.
28. Sethi, S., Walker, S., Drewes, J., Xu, P. "Existing and emerging concentrate minimization & disposal practices for membrane systems." *Florida Water Resources Journal* (2006):40,42,44,46,48.
29. Sethi, 2006; Lattemann and Höpner, 196.
30. A thermocline is a layer of rapid temperature change in the water, usually separating a well-mixed surface layer and deep water layer. Al-Ghadban, A.N., F. Abdali, M.S. Massoud. "Sedimentation rate and bioturbation in the Arabian gulf." Environment International, Vol. 24, No. 1/2, (1998) pp. 23-31.
31. Lattemann and Höpner, 195; NRC, 2008.
32. Alameddine, M. El-Fadel. Brine discharge from desalination plants: a modeling approach to an optimized outfall design. *Desalination* 214 (2007) 241–260.
33. Lattemann and Höpner, 194.
34. R.M. Reynolds, Physical oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman – results from the Mt. Mitchell expedition, *Marine Pollution Bulletin* 27 (1993) 35–59; Brewer, Peter G., D. Dyrssen. "Chemical oceanography of the Persian Gulf." Prog. Oceanog. Vol. 14 (1985) 41-55.
35. Smith, Ronald, Anton Purnama, H.H. Al-Barwani. "Sensitivity of hypersaline Arabian Gulf to seawater desalination plants." *Applied Mathematical Modeling 31* (2007) 2347–2354.
36. Sheppard, Charles, Mohsen Al-Husiani, F. Al-Jamali, Faiza Al-Yamani, Rob Baldwin, James Bishop, Francesca Benzoni, Eric Dutrieux, Nicholas K. Dulvy, Subba Rao V. Durvasula, David A. Jones, Ron Loughland, David Medio, M. Nithyanandan, Graham M. Pilling, Igor Polikarpov, Andrew R.G. Price, Sam

APPENDIX 5: ENDNOTES

Purkis, Bernhard Riegl, Maria Saburova, Kaveh Samimi Namin, Oliver Taylor, Simon Wilson, Khadija Zainal. "The Gulf: A young sea in decline." *Marine Pollution Bulletin 60* (2010) 13–38.

37. This statistic is called the mean residence time of water (MRT). Reynolds, Physical oceanography, 35.
38. Environmental Agency (EAD) *Abu Dhabi Water Resource Master Plan – Draft*, Annex 4 Potable Water Demand, 5.
39. A. Randall, "Property entitlements and pricing policies for a maturing water economy," *Australian Journal of Agricultural Economics* 25 no 3. (1981): 195–212.
40. EAD, Water Resources in Abu Dhabi Emirate, 2009, p. 87.a
41. EAD, Water Master Plan for the Emirate of Abu Dhabi, 2009. P. 29-30.
42. Ibid, p.30.
43. Abu Dhabi Tourism Authority. "Population." http://www.visitabudhabi.ae/en/uae.facts.and.figures/population.aspx. (accessed April 10, 2010).
44. Ibid.
45. Todorova, Vesela,"Abu Dhabi's water conservation plans." *The National*. (May 18, 2008). http://www.thenational.ae/article/20080518/NATIONAL/970674321. (accessed April 10, 2010).
46. Central Intelligence Agency The World FactBook. "Middle East: The United Arab Emirates." https://www.cia.gov/library/publications/the-world-factbook/geos/ae.html, (accessed April 10, 2010).
47. P. van de Zaage and H.H.G Savenije "Water as a economic good: The value of pricing and the failure of markets" *Value of Water* Research Report Series 19 UNESCO-IHE Institute for Water Education (July 2006) 11-12
48. Ibid, 17
49. Ibid.
50. Ibid, 19
51. Executive Affairs Authority, "Economic Affairs," http://eaa.abudhabi.ae/Sites/EAA/Navigation/EN/AdvisoryUnits/economic-affairs,did=122220,render=renderPrint.html. (accessed April 10, 2010).
52. Zawya Ltd. "Rising demand-supply gap brings GCC water policy in the spotlight." http://www.zawya.com/Story.cfm/sidZAWYA20091222043601/Rising%20demand-supply%20gap%20brings%20GCC%20water%20policy%20in%20the%20spotlight. (accessed April 10, 2010).
53. Santa Fe, New Mexico Government, "Sangre de Cristo Water Division," Santa Fe, New Mexico Government, http://www.santafenm.gov/index.aspx?nid=269, (accessed March 29, 2010).
54. Queensland Water Commission, "Queensland Water Commission," Queensland Water Commission, http://www.qwc.qld.gov.au/HomePage, (accessed April 1, 2010).
55. Royal Commission of Water, "Royal Commission of Water," Ministry of Water and Irrigation, http://www.mwi.gov.jo/English/MWI/RCOW/Pages/default.aspx, (accessed April 1, 2010).
56. Water Information. "Information Sheet 3> The Australian Water Resources Information System." Australian Government Bureau of Meteorology. http://www.bom.gov.au/water/about/publications/document/InfoSheet_3.pdf (accessed April 1, 2010).
57. Water Information. "Information Sheet 3> The Australian Water Resources Information System." Australian Government Bureau of Meteorology. http://www.bom.gov.au/water/about/publications/document/InfoSheet_3.pdf, (accessed April 1, 2010).
58. Water Information. "Information Sheet 3> The Australian Water Resources Information System." Australian Government Bureau of Meteorology. http://www.bom.gov.au/water/about/publications/document/InfoSheet_3.pdf, (accessed April 1, 2010).
59. Jordan Ministry of Water and Irrigation, "About MWI." Ministry of Water and Irrigation. http://www.mwi.gov.jo/english/mwi/Pages/default.aspx (accessed April 1, 2010).
60. Jordan Ministry of Water and Irrigation, "National Water Master Plan (NWMP)." Ministry of Water and Irrigation. http://www.mwi.gov.jo/english/mwi/NationalPlan/Pages/default.aspx (accessed April 1, 2010).
61. Taha, Suzan and Philipp Magiera. *National Water Master Plan*. Amman: Ministry of Water and Irrigation. http://www.mwi.gov.jo/Arabic/MWI/NationalPlan/Documents/nwmp%20brochure.pdf
62. El-Naser, Nazim K. *Management of Scarce Water Resources: A Middle Eastern Experience*. Southampton: WIT Press, (2009).
63. Euro-Mediterranean Information System on know-how in the Water Sector. "Jordan: National Water Strategy 2008-2022 Adopted." EMWIS. http://www.emwis.net/countries/fol749974/country045975/national_program/thematicdirs/news/jordan-jd586b-water-strategy-finalized (accessed April 1, 2010).
64. Water Information System Data Online Management. "About WISDOM." Central Water Commission India. http://www.india-water.com/index.asp (accessed April 1, 2010).
65. Water Information System Data Online Management. "About WISDOM." Central Water Commission India. http://www.india-water.com/index.asp (accessed April 1, 2010).
66. Water Information System Data Online Management. "About WISDOM." Central Water Commission India. http://www.india-water.com/index.asp (accessed April 1, 2010).
67. Central Ground Water Board. "Regional Data Centre." Central Ground Water Board, Ministry of Water Resources. http://cgwb.gov.in/ncr/rodc.htm (accessed April 1, 2010).

APPENDIX 5: ENDNOTES

68. Water Information System Data Online Management. "About WISDOM." Central Water Commission India. http://www.india-water.com/index.asp (accessed April 1, 2010).
69. Cheng, Caleb. "Online Resources for Environmental Impact Analysis: California Data Exchange Center (CDEC). Online Data Resources of California. http://ice.ucdavis.edu/education/esp179/?q=node/70 (accessed April 3, 2010).
70. Cheng, Caleb. "Online Resources for Environmental Impact Analysis: California Data Exchange Center (CDEC). Online Data Resources of California. http://ice.ucdavis.edu/education/esp179/?q=node/70 (accessed April 3, 2010).
71. Department of Water Resources. "California Data Exchange Center." www.water.ca.gov/floodmgmt/docs/CDEC_Brochure.pdf (accessed April 3*, 2010).*
72. California Data Exchange Program. "Overview of CDEC." Department of Water Resources. http://cdec.water.ca.gov/intro.html (accessed April 3, 2010).
73. Department of Water Resources. "California Data Exchange Center." www.water.ca.gov/floodmgmt/docs/CDEC_Brochure.pdf (accessed April 3*, 2010).*
74. Department of Water Resources. "California Data Exchange Center." www.water.ca.gov/floodmgmt/docs/CDEC_Brochure.pdf (accessed April 3*, 2010).*
75. National Water Initiative, http://www.nwc.gov.au/www/html/117-national-water-initiative.asp
76. Gold Coast Waterfuture Strategy PDF, http://www.goldcoastwater.com.au/attachment/goldcoastwater/pressure_leakage_final_report_dewha.pdf (accessed March 29, 2010).
77. Mead, S.P., Schlinger, C. M., Auberle, W. M., Roberts, M. S. A Water/Energy Best Practices Guide for Rural Arizona's Water and Wastewater Systems. Northern Arizona University. 2009. Retrieved April 5, 2010 from http://www.waterenergy.nau.edu/docs/Best_Practices_Guide_2009.pdf (accessed March 29, 2010).
78. Behavioral inducements as a 'nudge,' is defined by Richard H. Thaler and Cass R. Sunstein, *Nudge* (New York: Penguin, 2009). For more on behavioral economics, see Sendhil Mullainathan and Richard H. Thaler. "Behavioral Economics," Massachusetts Institute of Technology Department of Economics Working Paper Series, Working Paper 00-27 September 2000; Robin C. Winkler and Richard A. Winett, "Behavioral Interventions in Resource Conservation," *American Psychologist*, April 1982, 420-435; E. Scott Geller, Jeff B. Erickson and Brenda A. Buttram, "Attempts to Promote Residential Water Conservation with Educational, Behavioral and Engineering Strategies," *Population and Environment,* Vol. 6(2), Summer 1983, 96-112.
79. See the Heroes of the UAE website for more: <http://www.heroesoftheuae.ae/en>.
80. C.H. Midden, "Using Feedback, Reinforcement and Information to reduce Energy Consumption in Households: A Field-Experiment" *Journal of Economics Psychology* 3 (1983): 65-68.
81. Margot Kuttschreuter and Oene Wiegman. "Crime Prevention and the Attitude Toward the Criminal Justice System: The Effects of a Multimedia Campaign." *Journal of Criminal Justice* 26 (1997): 441-452.
82. Robert Wicks. "Understanding audiences: learning to use the media constructively." New Jersey: Lawrence Erlbaum Associates, (2000).
83. Arthur J. Lurigio and Dennis P. Rosenbaum. "The effects of mass media on crime prevention awareness, attitudes, and behavior: The case of crime stoppers." *American Journal of Criminal Justice.* 15, no. 2, (1991). http://www.springerlink.com.ezproxy.cul.columbia.edu/content/b658r6q774kn7524/fulltext.pdf.
84. The program name has changed according to the water consumption target because of the changing water levels in the reservoir. The program is currently called "Target 170," not "Target 140." See http://www.aurum3.com/tag/target-140/ and www.target170.com.au/ for more information.
85. Patrick Whyte, "Australia knows something about drought" *Los Angeles Times,* January 4, 2009. Online edition. http://www.latimes.com/news/printedition/asection/la-oe-whyte4-2009jan04,0,270396.story, (accessed April 1, 2010).
86. AED Center for Environmental Strategies. "From CRISIS to CONSENSUS: *A New Course for* Water Efficiency *in* JORDAN," (No Date) www.aed.org/Publications/upload/crisis_to_consensus.pdf.
87. (image http://www.aceee.org/conf/mt06/con1a-niblett.pdf).
88. AED Center for Environmental Strategies. "From CRISIS to CONSENSUS: *A New Course for* Water Efficiency *in* JORDAN," (No Date) www.aed.org/Publications/upload/crisis_to_consensus.pdf.
89. Academy for Educational Development. "Water Efficiency and Public Information for Action (WEPIA) Program, 2000-2005 Final Report." USAID/Jordan, 2005. http://jordan.usaid.gov/upload/keydocs/WEPIA%20Final%20Report.pdf
90. Ginny Hill. "Comic answer to Yemen water crisis." *BBC News,* September 4, 2008. <http://news.bbc.co.uk/2/hi/middle_east/7595552.stm>.
91. Jen Chung. "City Unveils Green Campaign GreeNYC." *Gothamist.* June 26, 2007. <http://gothamist.com/2007/06/26/city_unveils_gr.php>.
92. GreeNYC. "Anti-Idling Campaign." 2009. Accessed at <http://www.drivingsustainability.com/files/NYC_Bloomberg_AntiIdling%20Report_December%202009.pdf.>
93. UAE Interact. "Medial and Information." <http://www.uae.gov.ae/Government/media.htm>.
94. Ibid
95. NationMaster. "Time Series> Media> Radio receivers> United Arab Emirates," (2010), http://www.nationmaster.com/time.php?stat=med_rad_rec&country=tc. (accessed April 8, 2010).
96. Edmund Ghareeb. "New Media and the Information Revolution in the Arab World: An Assessment." *Middle East Journal,* 54, no. 3 (2000): 395-418.
97. Internet World Stats, "United Arab Emirates- Internet Usage and Marketing Report," (2009), http://www.internetworldstats.com/me/ae.htm (accessed April 29, 2010).
98. Mohamed Kirat, "Promoting online media relations: Public relations departments' use of Internet in the UAE," *Public Relations Review* 33, no. 2 (2007): 166-74 http://vnweb.hwwilsonweb.com.ezproxy.cul.columbia.edu/hww/results/external_link_maincontentframe.jhtml?_AARGS=/hww/results/results_common.jhtml.42 (accessed April 29, 2010).

APPENDIX 5: ENDNOTES

99. National Media Council. “UAE Yearbook 2009.” (2009) <http://www.uaeinteract.com/uaeint_misc/pdf_2009/data/engl_yearbk_09.pdf>
100. Research and Markets. “United Arab Emirates - Telecoms, Mobile and Broadband.” 2009. <http://www.researchandmarkets.com/reports/1081229/united_arab_emirates_telecoms_mobile_and.htm>.
101. As of June 2009, more than 780,000 (sources show 840,000) people in the UAE had activated a Facebook account. http://www.thenational.ae/apps/pbcs.dll/article?AID=/20090720/BUSINESS/707209936/0/FOREIGN
102. AED Academy for Educational Development. “Water Efficiency and Public Information for Action (WEPIA) Program, 2000-2005 Final Report.” USAID/Jordan. (2005).Accessed at <http://jordan.usaid.gov/upload/keydocs/WEPIA%20Final%20Report.pdf>.
103. Michael S. Pallack, David A. Cook, and John J. Sullivan."Commitment and Energy Conservation." In *Applied Social Psychology Annual*, Vol. 1, ed. L. Bickman, (Beverly Hills: Sage Publications, 1980) 235-53.
104. Victor Flatt, “Act Locally, Affect Globally: How the structure of Local government makes it the Best Arena for Engagement and Work with the private Sector to control Environmental Harms”, University of Houston Law Center (2006).
105. 1.68 million is 96% of the 1.75 million people living in Abu Dhabi. United States Central Intelligence Agency, “The World Fact Book: United Arab Emirates,” CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/ae.html.
106. Ali Khan Atallah and M. Malkawi. “Water conservation through Islamic public awareness in the Eastern Mediterranean M.Z. Region.” *Eastern Mediterranean Health Journal* 5, no. 4 (1999): 785-797.
107. Ibid.
108. The average person uses 3 to 4 liters of water during ablution. If 1.68 million people perform ablution 5 times a day (before each call to prayer) that accounts for over 5 million liters of water used a week on ablution alone. For more information on water conservation and ablution practices see Ir Noor Azahari Zainal Abidin, “Operational Aspects of Water Demand Management” Ministry of Energy, Green Technology and Water, Malaysia. Accessed at <http://www.jba.gov.my/index.php/muat-turun/doc_download/78-operational-aspects-of-water-demand-management>; Kuala Lumpa. “Muslim washing rite goes hi-tech with "wudu" machine.” *Reuters*. January 31, 2010. Accessed at <http://www.reuters.com/article/idUSTRE6100FM20100201>.
109. Attari, Shahzeen Z., Michael L. DeKay, Cliff I. Davidson, and Wändi Bruine de Bruin. “Public Perceptions of Energy Consumption and Savings,” Columbia University (2010) unpublished.
110. Midden, Cees, Joanne Meter, Mieneke Weenig, and Henk Zieverink, “Using Feedback, Reinforcement and Information to Reduce Energy Consumption in Households: A Field-Experiment,” *Journal of Economics Psychology* 3 (1983): 65-68.
111. Attari, 2010.
112. Executive Affairs Authority. “Economic Affairs.” http://eaa.abudhabi.ae/Sites/EAA/Navigation/EN/AdvisoryUnits/economic-affairs,did=122220,render=renderPrint.html. (accessed April 10, 2010).
113. Zawya Ltd. “Rising demand-supply gap brings GCC water policy in the spotlight.” http://www.zawya.com/Story.cfm/sidZAWYA20091222043601/Rising%20demand-supply%20gap%20brings%20GCC%20water%20policy%20in%20the%20spotlight. (accessed April 10, 2010).
114. Colorado Springs Utilities provides a useful xeriscape gardening demonstration at <http://www.csu.org/wa/xeri/xeriscape.jsp>.
115. Marie Iannotti, “Xeriscape Gardening: Planning for a Water Wise Garden; A Common Sense Approach to ‘What Plant Where?’” About.com Guide, available at <http://gardening.about.com/od/gardendesign/a/Xeriscaping.htm>.
116. The Nature Conservancy, “Car Washing and the Environment,” accessed at < http://www.nature.org/wherewework/northamerica/states/indiana/misc/art22036.html>; Chris Brown, Water Conservation in the Professional Car Wash Industry, A Report for the International Carwash Association, available at <http://www.carwash.org/operatorinformation/research/Pages/EnvironmentalReports.aspx>.
117. See references to various companies at the Nature Conservancy (http://www.nature.org/wherewework/northamerica/states/indiana/misc/art22036.html>) and the International Carwash Association (http://www.carwash.org/operatorinformation/Environment/Pages/default.aspx).
118. John E. Petersen, Vladislav Shunturov, Kathryn Janda, Gavin Platt and Kate Weinberger, “Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives” *International Journal of Sustainability in Higher Education,* Vol. 8 No. 1, 2007, 16-33.
119. Richard Conniff, “Using Peer Pressure as a Tool to Promote Greener Choices.” *Yale Environment 360* April 16, 2009, accessed at <http://e360.yale.edu/content/feature.msp?id=2141>.
120. Midden, 1983
121. Leslie Kaufman, “Utilities Turn Their Customers Green, With Envy” *New York Times*, January 30, 2009, accessed at <http://www.nytimes.com/2009/01/31/science/earth/31compete.html?_r=1>.
122. Farzaneh Roudi-Fahimi, et al. “Finding the Balance; Population and Water Scarcity in the Middle East and North Africa.” Population Reference Bureau (June 2002) http://www.prb.org/Publications/PolicyBriefs/FindingtheBalancePopulationandWaterScarcityintheMiddleEastandNorthAfrica.
123. Ibid
124. Mariam M. Al Serkal “Sharjah to introduce power saving system” *Gulf News,* February 27, 2008, http://gulfnews.com/news/gulf/uae/environment/sharjah-to-introduce-power-saving-system-1.86682.
125. Dubai Electric and Water Authority, accessed at <http://www.dewa.gov.ae/tariff/tariffdetails.aspx> ; Emmanuelle Landais. “Dubai introduces new rates to curb use of electricity and water” *Gulf News,* February 17, 2008, http://gulfnews.com/news/gulf/uae/general/dubai-introduces-new-rates-to-curb-use-of-electricity-and-water-1.85172.
126. Ibid

APPENDIX 5: ENDNOTES

127. Ibid
128. A. Fadlelmawla, "Towards Sustainable Water Policy in Kuwait: Reforms of the Current Practices and the Required Investments, Institutional and Legislative Measures" *Water Resources Management*, 23 no. 10 (2009): 1969-1987.
129. Fadlelmawla, 2009, 1974
130. Ibid
131. Ibid
132. Lin Crase Brian Dollery, Joel Byrnes, " An intersectoral comparison of Australian water reforms" *Water Policy* 10 (2008) 43–56
133. Ibid.
134. Tom Jones "Pricing Water" *OECD Observer* No. 236, March 2003 http://www.oecdobserver.org/news/fullstory.php/aid/939/Pricing_water.html
135. Stephen Maxwell Wheeler and Timothy Beatley. *The Sustainable Urban Development Reader,* London: Routledge, (2004).
136. Abu Dhabi Urban Planning Council. "Al Bateen Waterfront Design Guidelines," *Sustainable Urban Planning* (2010), http://www.upc.gov.ae/en/SustainableUrbanDesign/AlBateenWaterfrontDesign.aspx
137. Gary Brown and Sabitha Sakkir. "The Vascular plants of Abu Dhabi Emirate," *Terrestrial Environment Research Center* (2004), http://www.ead.ae/TacSoft/FileManager/Publications/reports/TERC/plantchecklistv1_2.pdf
138. See, for example, Colorado Water Wise at <http://www.xeriscape.org/>; Sustainable Sources' "Xeriscape," at <http://xeriscape.sustainablesources.com/>; and the Xeriscape Council of New Mexico at <http://www.xeriscapenm.com/>.
139. UAE Interact., "Municipality of Abu Dhabi City Approves Landscaping Layouts of 4 Major Intersections," UAE Interact, (2010), http://www.uaeinteract.com/docs/Municipality_of_Abu_Dhabi_City_approves_landscaping_layouts_of_4_major_intersections/40334.htm
140. Nancy Lucid, "Hardscape," Santa Clara University, (2005). Accessed at <http://www.scu.edu/stclaregarden/sustainable/hardscape.cfm>.
141. Eastern Municipal Water District, "EMWD's Water Wise Demonstration Garden 2270 Trumble Road, Perris," (2009), Accessed at <http://www.emwd.org/conservation/demo-garden.html#1>.
142. Eastern Municipal Water District, "EMWD's Water Wise Demonstration Garden 2270 Trumble Road, Perris," (2009), <http://www.emwd.org/conservation/demo-garden.html#1>.
143. A.M. VanDerZanden, "Hardscapes for Sustainable Landscapes," Oregon State University Extension Service (2003), Accessed at <http://extension.oregonstate.edu/catalog/pdf/ec/ec1535.pdf>.
144. Amir Taebi and Ronald Droste, "Pollution Loads in Urban Runoff and Sanitary Wastewater," Science of the Total Environment. 327, (2004)
145. City of Santa Rosa, "Water Efficient Landscape Policy," (2007), http://www.downtownsr.org/doclib/Documents/updatedwaterefficientlandscapepolicy.pdf
146. Stuart Warren and Ted Bilderback., "Irrigation Timing: Effect on Plant Growth, Photosynthesis, Water-Use Efficiency and Substrate Temperature," *Acta Hort.*644, (2004), http://www.ces.ncsu.edu/depts/hort/nursery/research/reference-publications/Warren-Bilderback-irrig-timing.pdf
147. Odeh R. Al-Jayyousi, "Greywater Reuse: Towards Sustainable Water Management," *Desalination* 156, no. 1-3 (2003)
148. Nyree Stenekes, Hal Colebatch, David Waite, and Nick Ashbolt, "Risk and Governance in Water recycling: Public Acceptance Revisited," *Science Technoloy and Human Values* 31, no 107 (2006).
149. Ibid.
150. Water Resource Master Plan, 2009, 28
151. Environment Agency – Abu Dhabi (EAD) *AbuDhabi Water Resource Master Plan – Draft*, 28.
152. EAD, *AbuDhabi Water Resource Master Plan – Draft*, 13.
153. National Media Council. "UAE Yearbook 2009." 2009, 143
154. EAD, *AbuDhabi Water Resource Master Plan – Draft*, 34.
155. Environment Agency – Abu Dhabi (EAD), *Water Resources of Abu Dhabi Emirate, United Arab Emirates* (Abu Dhabi: Environment Agency – Abu Dhabi, 2006), 10.
156. Joseph Casas, Mahmoud Solh, and Hala Hafez. *WANA NARS Study*, Montpelier: French National Institute for Agriculture Research, (1999). Accessed at <http://www.icarda.org/NARS/WANA_Region.pdf>.
157. Ibid.
158. International Center for Biosaline Agriculture (ICBA): The ICBA was established in 1999 by the Islamic Development Bank (IDB) and the Government of the United Arab Emirates (UAE). The ICBA was founded in response the increasing international uncertainty of freshwater available for agriculture purposes. The mission of the ICBA is *"to demonstrate the value of saline water resources for the production of environmentally and economically useful plants, and to transfer its research results to national research services and communities in the Islamic world and elsewhere.* ICBA has three fundamental programs: integrated water resource system, marginal quality resources, and capacity building and knowledge-sharing. Since its inception the ICBA boasts successes including creating over twenty-four research and development programs and having trained over 850 individuals including 250 UAE nationals. The ICBA is located roughly 25 km south of Dubai near Al Ruwayyah and consists of 100 hectares, 35 of which have been developed for irrigated agriculture. See <http://www.biosaline.org/>.
159. Global Water Partnership Toolbox: Integrated Water Resource Management, *Tunisia: Reform of Irrigation Policy and Water Conservation – Case #19*, Global Water Partnership (GWP), 2008, http://www.gwptoolbox.org/images/stories/cases/en/cs%2019%20tunisia.pdf.
160. Debra Driskill, interview by authors, New York, NY, 2010.

APPENDIX 5: ENDNOTES

161. Robert N. King, "Identifying Effective and Efficient Methods To Educate Farmers about Soil Sampling," *Journal of Extension* 37, no. 1 (1999), http://www.joe.org/joe/1999february/rb3.php.
162. United Arab Emirates - Census Higher Authority, *Census 2005*, http://www.tedad.ae/english/statistic/economic_activity.html.
163. Water Resource Master Plan, 2009, 28
164. Ibid.
165. The World Health Organization, "WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater – Volume 2 Wastewater use in agriculture" (World Health Organization, 2008) , xx
166. Ibid, xxiii.
167. Ibid, 101.
168. Ibid, Appendix III, 2.
169. Abu Dhabi Tourism Authority, "Abu Dhabi's MICE Potential Expanding, Says Expert," Abu Dhabi Tourism Authority, Press Release, (15 February 2009), http://www.abudhabitourism.ae/en/news/tom.hulton.aspx
170. North Carolina Department of Environment and Natural Resources. "Hotel/Motel Waste Reduction." Reference Collection. http://www.p2pays.org/ref/01/00421.pdf. (accessed April 8, 2010).
171. O'Neill & Siegelbaum and The RICE Group. "Hotel Water Conservation. A Seattle Demonstration." http://www.corecentre.co.in/Database/Docs/DocFiles/hotel_water.pdf. (accessed April 8, 2010).
172. ArabianBusiness.com. "Water waste and conservation." http://www.arabianbusiness.com/index.php?option=com_content&view=article&id=495859. (accessed April 8, 2010).
173. National Public Radio. "Stakes High for Las Vegas Water Czar." http://www.npr.org/templates/story/story.php?storyId=10939792. (accessed April 8, 2010).
174. Aldar Hotels & Hospitality. "Abu Dhabi Hotel Plan Current and Future." http://www.b-e-x.com/downloads/Raman%20Khanna,%20Aldar.pdf. (accessed April 8, 2010).
175. Abu Dhabi Tourism Authority. "About Abu Dhabi Tourism Authority (ADTA)." http://www.abudhabitourism.ae/en/main/about-adta.aspx. (accessed April 8, 2010).
176. Abu Dhabi Tourism Authority. "Vision, Mission, Values & Quality Policy." http://www.abudhabitourism.ae/en/main/vision.mission.and.values.aspx. (accessed April 8, 2010).
177. Abu Dhabi Tourism Authority. "1st Quarter 2007-Hotel Statistics Summary by Hotel Classification." http://www.abudhabitourism.ae/en/info/first.quarter.aspx. (accessed April 8, 2010). Abu Dhabi Tourism Authority. "2nd Quarter 2007-Hotel Statistics Summary by Hotel Classification." http://www.abudhabitourism.ae/tacme/admin/content/file/2nd%20quarter%202007/22q07.pdf. (accessed April 8, 2010).
178. It should be noted that reductions in hotel star/diamond status are anticipated with the new requirements and that compliance will be difficult to meet without incentives. Therefore, it is our recommendation to honor subsidies to maintain status based upon the average annual occupancy rate of each hotel classification. See Exhibit 1. Financial incentives are also recommended in Other Potential Strategies Section.
179. Research Department of the Caribbean Tourism Organization. "Hotel Classification System Summary of articles and Information on Hotel Classification System." Accessed at http://www.onecaribbean.org/content/files/hotelcalssification(1).pdf. (accessed April 8, 2010).
180. According to a study under the LEED system, it takes about 3-5 years for businesses to recoup the costs of energy retrofits: http://nreionline.com/green-building/commercial-real-estate-on-green/ and it can take anywhere from 1-5 years for compliance for extensive fire code system retrofits in hotels in Ontario: http://nreionline.com/green-building/commercial-real-estate-on-green/. No information was found on a timeline for compliance for LEED or BREAM; however, the above information presents a payback period and an extensive retrofit period. Timeline will depend on the size of the hotel, type of water retrofits, and number of retrofits required per hotel classification, e.g., showerheads may take less time to retrofit than a water and condensate recovery system
181. The Corporate Social Responsibility Newswire. "Harvesting Energy –Going Green! New York Marriott Downtown is First Hotel in New York City to Install Energy-Efficient Tri-generation Plant." http://www.csrwire.com/press/press_release/25245-Harvesting-Energy-Going-Green-New-York-Marriott-Downtown-is-First-Hotel-in-New-York-City-to-Install-Energy-Efficient-Tri-generation-Plant-. (accessed April 8, 2010).
182. John Montano, phone interview by Jill Kano, February, 23, 2010, New York Marriott Downtown, New York, New York.
183. Southern Nevada Water Authority. "Water Efficient Technologies." http://www.snwa.com/html/cons_wet.html. (accessed April 8, 2010).
184. Southern Nevada Water Authority. "Water Smart Landscapes Rebate. " http://www.snwa.com/html/cons_wsl.html. (accessed April 8, 2010).
185. Square feet to square meters conversion metric: 1 square foot = .093 squared meter.
186. Acres to meters squared conversion metric: 1 acre = 4,047 meters squared.
187. March, J.G., M. Gual and O. Orozco. "Experiences on greywater re-use for toilet flushing in a hotel (Mallorca Island, Spain)." *Desalination*, 164, no. 3, (2004): 241-47.
188. Southern Nevada Water Authority. "Linen Exchange Program. " http://www.snwa.com/html/cons_biz_linen.html. (accessed April 8, 2010).
189. Scientific American. "Hotel Case Study: Peer Pressure's Impact on the Environment." http://www.scientificamerican.com/article.cfm?id=hotel-case-study. (accessed April 8, 2010).
190. O'Neill & Siegelbaum and The RICE Group. "Hotel Water Conservation. A Seattle Demonstration." http://www.corecentre.co.in/Database/Docs/DocFiles/hotel_water.pdf. (accessed April 8, 2010)..

APPENDIX 5: ENDNOTES

191. Ibid.
192. Ibid.
193. Cao, Xiaoxin, Xia Huang, Peng Liang, Kang Xiao, Yingjun Zhou, Xiaoyuan Zhang, and Bruce Logan, "A New Method for Water Desalination Using Microbial Desalination Cells," *Environ. Sci. Technol*. 43 (2009): 7148-7152.
194. Cao, "A New Method," 7151.
195. Madwar, Karim, and Hani Tarazi, "Desalination techniques for industrial wastewater reuse," *Desalination* 152 (2002): 325-332.
196. Water Resources Master Plan, 2009, pg 33.
197. Sommariva, C., H. Hogg, and K. Callister, "Environmental impact of seawater desalination: relations between improvement in efficiency and environmental impact," *Desalination* 167 (2004): 439-444.
198. Mohamed, A.M.O., M. Maraqa, and J. Al Handhaly. "Impact of land disposal of reject brine from desalination plants on soil and groundwater," *Desalination* 182 (2005): 411-433.
199. Alberti, Federica, Nicola Mosto, and Corrado Sommariva, "Salt production from brine of desalination plant discharge." *Desalination and Water Treatment* 10 (2009): 128-133.
200. Ahmed, Mushtaque, Aro Arakel, David Hoey, Muralee R. Thumarukudy, Mattheus F.A. Goosen, Mansour Al-Haddabi, and Abdullah Al-Belushi. "Feasibility of salt production from inland RO desalination plant reject brine: a case study," *Desalination* 158 (2003): 109-117.
201. Alberti, "Salt production from brine," 129.
202. Alberti, "Salt production from brine," 130.
203. Ahmed, "Feasibility of salt production," 112.
204. Water Resources Master Plan, 2009, pg 28.
205. Crosbie, Ewan, "Understanding and Management of Atmospheric Water." (presentation, Rowan Williams Davies & Irwin Inc. (RWDI), Abu Dhabi, UAE, March 17, 2010).
206. Schlumberger Water Services. "Aquifer Storage and Recovery in Arid Environments: Abu Dhabi, United Arab Emirates," Schlumberger Water Services (July 1, 2007), http://www.slb.com/~/media/Files/water/case_studies/asr_abudhabi.ashx.
207. Schlumberger Water Services 2007
208. Schlumberger Water Services 2007
209. Schlumberger Water Services 2007
210. Vinoth Kumar et al., "Performance Study on Solar Still with Enhanced Condensation," *Desalination*, 203 (2008): 51-61.
211. Jenny Lindblom and Bo Nordell, "Water Production by Underground Condensation of Humid Air," *Desalination*, 198 (2006).
212. Badr Habeebullah, "Potential Use of Evaporator Coils for Water Extraction in Hot and Humid Areas," *Desalination*, 237 (2009).
213. J Olivier et al., "The implementation of fog water collection systems in South Africa," *Atmospheric Research*, 64 (2002): 227-38.
214. Olivier et al. 2002, 227-38.
215. Estrela, Maria, José A. Valiente, David Corell, David Fuentes, "Fog Collection in a Region of the Western Mediterranean Basin: Evaluation of the use of Fog Water for the Restoration of Wildfire Burnt Areas," *Fundación CEAM*, (2009), http://portales.gva.es/ceam/ceamet/investigacion/publicaciones/FOG-2004.pdf.
216. Crosbie, Ewan,"Understanding and Management of Atmospheric Wate,." (presentation, Rowan Williams Davies & Irwin Inc. (RWDI), Abu Dhabi, UAE, March 17, 2010).
217. Hari Srinivas, "An Introduction to Rainwater Harvesting," *The Global Development Research Center*, http://www.gdrc.org/uem/water/rainwater/introduction.html.
218. Srinivas.
219. Srinivas.
220. Srinivas.
221. Abdulla, Fayez A. and A.W. Al-Shareef, "Roof rainwater harvesting systems for household water supply in Jordan," *ScienceDirect* 243 (2009).