Note de l'Ifri

Water and Energy in the GCC:
Securing Scarce Water in Oil-Rich Countries

Laura Parmigiani

September 2015

Centre Énergie

The Institut français des relations internationales (Ifri) is a research center and a forum for debate on major international political and economic issues.

Headed by Thierry de Montbrial since its founding in 1979, Ifri is a non-governmental and a non-profit organization.

As an independent think tank, Ifri sets its own research agenda, publishing its findings regularly for a global audience.

Using an interdisciplinary approach, Ifri brings together political and economic decision-makers, researchers and internationally renowned experts to animate its debate and research activities.

With offices in Paris and Brussels, Ifri stands out as one of the rare French think tanks to have positioned itself at the very heart of European debate.

The opinions expressed in this text
are the responsibility of the author alone.

ISBN: 978-2-36567-442-3

IFRI
27, RUE DE LA PROCESSION
75740 PARIS CEDEX 15 – FRANCE
Tel: +33 (0)1 40 61 60 00
Fax: +33 (0)1 40 61 60 60
Email: ifri@ifri.org

IFRI-BRUXELLES
RUE MARIE-THÉRÈSE, 21
1000 – BRUSSELS – BELGIUM
Tel: +32 (0)2 238 51 10
Fax: +32 (0)2 238 51 15
Email: info.bruxelles@ifri.org

WEBSITE: *Ifri.org*

Executive Summary

Water scarcity in the Gulf Cooperation Council (GCC) states has traditionally been addressed by finding new ways of producing water. Desalination techniques have allowed these countries to satisfy their increasing water demand, driven by economic and demographic development. The high CAPEX and OPEX costs of desalinated water production are borne by the State through subsidies in the forms of low water and electricity prices. As this trend is not environmentally or economically sustainable, new strategies are now giving priority to cost recovery and efficient resource management.

This comparative study will show that in the GCC countries, whose oil or gas reserves are among the largest worldwide, the management of water and energy resources has been relying upon vertically integrated government agencies and companies, with water supply policies fuelled by cheap energy. Wealth redistribution coming from oil and gas revenues has been ensured through low or inexistent water and electricity tariffs.

Groundwater resources, which are the only water sources of the region (there are no surface waters available, except for few dams in Saudi Arabia), are quickly diminishing. Desalination has been developing very fast and now seems to be the only reliable form of supplying water for future requirements. Saudi Arabia alone might need 18 billion cubic meter (bcm) of fresh water per year by 2050 to sustain current consumption patterns. For this reason, huge amounts of energy will be required and the question of the right energy/water balance is at stake. Technological choices in the electricity sector will influence the way water is produced in the future, and vice versa. In particular, water production fuelled by gas or heavy fuel can be linked to power generation, enhancing efficiency but lowering flexibility. Membrane technologies, which require only electricity inputs, allow for a diversified energy and electricity mix but they have smaller critical sizes and therefore produce smaller desalinated water outputs. An overall transformation map will have to be drafted in each country to show the development plans of both electricity generation and water production. This would enable governments and their agencies to assess cross-sector spill-over effects in a timely manner.

The single buyer model has ensured stability and predictability of the water and electricity system and enabled policy makers to forecast precisely water and electricity demand. However, the assumption of simply adding new water or electricity capacity is no longer coherent since cheap, domestic fuel is not as abundantly

available as it was in the 1980s. The United Arab Emirates (UAE), Saudi Arabia and Kuwait are already short of natural gas.

New plans have therefore been drafted to fit into an overall strategy of process optimization and reflecting costs, in view of minimizing the impact on the wealth redistribution policy, while starting to raise awareness about the outmost importance of water for the future of the GCC population. If rising tariffs seem the most obvious action to take, other ambitious political decisions have to be addressed, such as the creation of a water law and an inter-GCC water pricing framework.

Keywords: GCC, water production, water sector costs, natural gas, energy security, diversification of supplies, electricity, consumer tariffs.

Table of contents

Methodology

The geographical perimeter of the study includes the following countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE). These countries form the Gulf Cooperation Council (GCC), which was established in 1981 in Abu Dhabi.

The case study analysis is restricted to fresh water in the Emirate of Abu Dhabi (which includes Abu Dhabi, Al Ain and Al Gharbia) with data from 2005 to the most recent time available.

The water-energy nexus will be mostly covered from the perspective of water. The main reason is that the energy sector consumes relatively smaller quantities of water than other sectors, such as agriculture. Despite the importance of tackling all water misuses, the impact of low water-intense power generation technologies is minimal in some countries.

Data concerning the overview of energy and water statistics have been collected from reference databases: government statistical websites, international organizations such as the International Energy Agency, the World Bank, the International Monetary Fund or oil and gas industry statistics (BP statistical reviews in particular).

Country based tariffs have been taken from regulatory bodies' databases and annual reports. When data were not available, interviews have been conducted with national agency representatives or private companies. It has to be noted that availability of groundwater consumption data is very limited or estimated.

The author presented the preliminary results of this research paper at the conference 'Fresh Water, its laws and its stakes in the Arab countries of the Gulf Cooperation Council' organized by Paris Sorbonne University Abu Dhabi, on January 22nd, 2015.

Introduction

Water scarcity is not a new issue for the inhabitants of the Gulf Cooperation Council (GCC) states. The quest for water has shaped population movements in the region as well as the creation of cities and trade. However, since the discovery of oil in most of the GCC countries, a dramatic increase in wealth and population has occurred, in particular in the United Arab Emirates (UAE), Saudi Arabia and Qatar, putting pressure on already very scarce water resources. Most importantly, some of these countries are diversifying their economies away from oil by fostering tourism. Two thirds of the world population is within a 6-hour-flight radius. The GCC countries are increasingly becoming a favorite travel destination. Also, major events, such as the selection of Doha for the next World Cup or Dubai for the World Expo 2020, are attracting investments and gigantic urban developments.

Water and energy are fundamental for this growth to be fully accomplished. With the development of technology, the increasing amounts of water have been progressively satisfied through desalination techniques. These techniques require great amounts of energy, either electricity or primary energy sources like fossil fuels (gas, diesel or coal in particular). A strong link between energy and water has thus been created. In a recent report, IRENA[1] stresses that worldwide 15% of global fresh water use is for energy production (including oil extraction) and 55% of water utilities' operating budget is due to energy costs.

This comparative study will show that in GCC states, which have the largest oil and gas reserves worldwide, the need to manage resources efficiently and economically has not been a priority so far. Chapter 1 will detail the relationship between water needs, desalination production, energy demand and social stability. It will show that the increasing needs of water and energy are related to economic growth and social stability, while the huge amounts of water and energy are supplied through expensive and subsidized policies, with no demand-side management. The analysis will then focus on government policies and regulations applied so far. It will address GCC steps toward common management of water that have been

1. IRENA, 'Renewable energy in the water, energy & food nexus' (Abu Dhabi, 2015) 22.

considered and will underline the main difficulties in realizing a shared approach.

In Chapter 2, the case study of Abu Dhabi will analyze in particular the security and environmental challenges facing this Emirate. Building on the conclusions of this case study, the chapter shows that the current energy-water system of the GCC countries is unsustainable. However, this is less a matter of costs, as financial funds are largely available in this region. Instead it is more an issue of supply security for both water and energy, as well as the permanent environmental damage making difficult any further desalination projects in Gulf waters.

The Energy-Water Connection: a Key for Social Peace and Prosperity in the GCC Region

Despite disparities in terms of geographical and population size or government structure and the degree of openness towards third countries, the history of the GCC states presents some common traits, in particular in the energy and water sectors. After the discovery of oil in most of these countries, GDP growth increased tremendously as oil and gas production began. Energy and water were therefore required to satisfy economic growth and growing population needs, affecting indigenous water resources that became scarcer. Desalination techniques have been ensuring a steady flow of fresh water, while cheap oil kept prices at a reasonable level. A stable and relatively transparent market for water and electricity production progressively took shape, while environmental and climate concerns drew the attention to policies adopted in the water sector.

Cheap energy and free water… come at a cost

While oil and gas incomes made governments and ruling families rich, their paternalistic-style and government over rentier states ensured legitimacy, as special benefits were attributed to citizens, in particular by means of cheap or free gasoline, electricity, natural gas and water. Since access to free or cheap water and energy became an undisputed right,[2] the increasing water and electricity needs have been satisfied by socially acceptable supply policies,[3] rather than by

2. Maïté de Boncourt, 'Energy Strategy of the GCC countries' (Paris, 2012) 12; Jim Krane, 'An expensive diversion: Abu Dhabi's renewable energy investment amid a context of challenging demand' (James A. Baker III Institute For Public Policy Rice University, Houston, 2014) 5-6. For more literature on rentier states see also: Giacomo Luciani, Steffen Hertog, Princes, Brokers, and Bureaucrats: Oil and the State in Saudi Arabia, Cornell University Press, 2009.

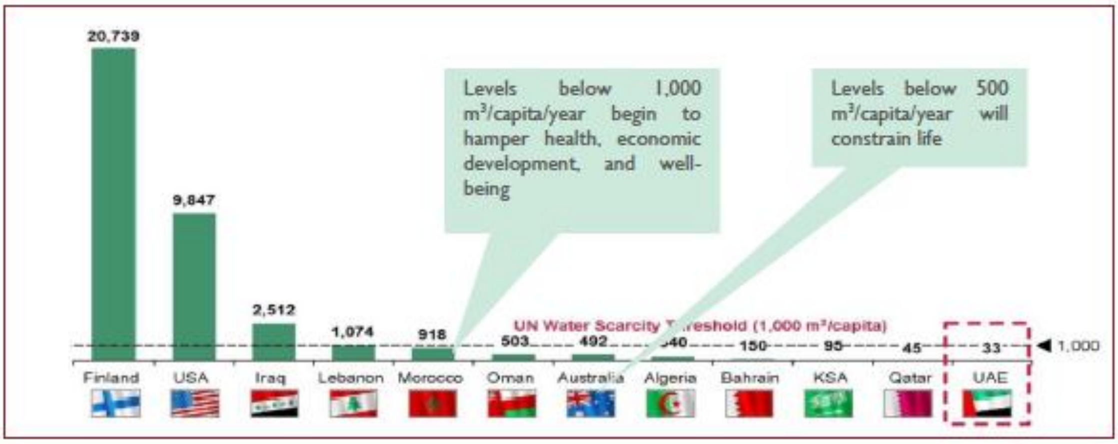
3. As Gwenn Okruhlik in 'Rentier Wealth, Unruly Law, and the Rise of Opposition: The Political Economy of Oil States', in Comparative Politics, April 1999, 295-315, explains, 'Not the simple receipt of oil revenue, but the choices made on how to spend it shape development. Money does not spend itself. Those acting in the name of the state make decisions, and the nature of the regime influences them'.

sustainable options. As a consequence, driven by pressing domestic demand, indigenous renewable water resources, which were already extremely scarce, have been replaced by desalination production, in order to leave groundwater resources for agriculture. Energy demand has increased almost proportionally to GDP and, to a lesser extent, to population growth.

The quest for water

All GCC countries lie below the UN water scarcity threshold and are considered in 'constrained life' situation.

Figure 1 Renewable water resources in m3/capita/year (2008)



Source: Environment Agency Abu Dhabi.

According to Droogers et al. (2012)[4], renewable water shortages (defined as the extra water resources that would be needed to satisfy consumption) for the GCC region could be 26 billion cubic meters (bcm) per year by 2050, or 77% of future consumption. In other words, GCC countries will be able to satisfy only 23% of their 2050 demand with their water resources. The Environment Agency Abu Dhabi (EAD) also confirms that by 2030 there will be a 30% increase in demand for water in a business-as-usual scenario. Abu Dhabi's groundwater resources will be depleted or will become too saline to be used.[5] It is most unlikely that desalinated water will be able to replace these gigantic amounts.

4. Droogers P., Immerzeel W., Terink W., Hoogeveen J., Bierkens M. F. P., van Beek L. P. H., and Debele D., 'Water resources trends in Middle East and North Africa towards 2050', *in Hydrology and Earth System Science*, 16, 3101–3114 (2012).

5. EAD, 'Maximizing recycled water use in the emirate of Abu Dhabi' (Annual Policy Brief, Abu Dhabi, 2013) 2.

Table 1 The potential fresh water shortage in the GCC region by 2050 (mcm/y)

Country	Current consumption (2010)	Current Shortag (2010)	Future Average consumption (2050)	Future shortage (2050)
Bahrain	226	195	391	379
Kuwait	508	0	1216	835
Oman	763	0	1709	1145
Qatar	325	83	395	174
Saudi Arabia	20 439	9 467	26 633	20 045
UAE	3370	3036	3389	3277
Total GCC countries	25 631	12 781*	33 733	25 855**

* 50% of extra water needed

** 77% of extra water needed

Source: Droogers et al. (2012)

Groundwater and agriculture

These figures raise the unavoidable question of understanding consumption patterns. It has first to be noted that the availability of water consumption and production data is very limited. While desalinated water production can be more easily metered, groundwater extraction and the re-use of water are more difficult to assess.

From an overall water system perspective, the biggest consumer of fresh water is agriculture, which usually draws its water resources from aquifers. Agriculture represents around 70% of water consumption in most of the GCC countries, following a common trend in the GCC states, since the 1970s, to strengthen food security. Policies favoring domestic food production were put in place to help fostering and sometimes (as in the extreme case of Saudi Arabia) achieving self-sufficiency in basic crops, milk and other few products.[6] Groundwater is given for free to farmers while electricity tariffs are subsidized. Groundwater resources have been therefore used extensively to sustain agriculture production in the desert, despite of their already scarce status.

6. FAO, 'Groundwater Management in Saudi Arabia, Draft Synthesis Report' (Rome, 2009), p7 and Eckart Woertz, 'Arab Food, Water and the Big Gulf Landgrab that Wasn't', in The Brown Journal of World Affairs (Princeton, 2014), p1.

With the substantial financial revenues from the oil industry, decisions to trigger a change in these policies were postponed, because of the risk of confrontations or social tensions.[7] However, the reality check with current and future domestic water resources is changing the attitude of the GCC monarchies towards some public policies.

Wastewater: a partial solution

Facing a water crisis that could endanger the economy and society as a whole, GCC countries are progressively abandoning their food security policies and focusing on measures to improve farming technology, early detection of leaks or metered consumption. They are also finding new sources of water.

In particular, water treatment and reuse have been increasingly seen as a valuable source for some industrial activities and landscape irrigation. While Treated Sewage Effluents (TSE) are not sufficient to substitute for groundwater in agriculture, they can still 'displace' some amounts of high quality desalinated water currently used for irrigation of golf course, resorts or hotels. This water could be put to better uses, such as domestic consumption, thus helping to reduce the need for more desalination capacity. Also, the geographical location of treatment plants is usually close to industries and cities and makes it logical to use TSE for landscape or forest irrigation. With improvements in treatments and quality, TSE water will eventually be affected to the domestic sector too. An example of 100% reuse and redistribution policy is found in Singapore,[8] which all GCC countries look into as the most advanced water management system.

In Saudi Arabia, 2 mcm of water were reused in agriculture in 2010, landscaping and industrial usages, and they could increase to 6 mcm by 2035.[9] Although it is still early days, many companies, including Saudi Aramco, are increasingly becoming aware of the necessity of water consumption efficiency and are now aiming at

7. 'Wealth has relaxed many of the traditional constraints of development and enabled the state to avoid really tough decisions or, when decisions are made, to repeal them quickly if opposition is met. Thus, the state can effectively postpone confrontations on property rights, monopolies, the enforcement of contracts, and efficient sectorial resource allocation.' Gwenn Okruhlik (1999).

8. Information collected at the International Water Summit (Abu Dhabi, January 2015) through the presentation of Maurice Neo, Director for Industry Development Public Utilities Board (PUB) of Singapore. In Singapore, water tariffs are structured so that tariffs rise with greater use. Also, all the means are applied to recover water: collection of rain water (storage), imports from Malaysia (in the form of an exchange, since water cannot be bought or sold as a commercial good), reuse to produce 'new water' which covers 30% of daily demand based on 100% recovery, and desalinated water.

9. King Abdullah University of Saudi Arabia, 'Strategic Study' (Riyadh, 2012) 4-5.

onsite reuse in oil production facilities. According to a study conducted by the Japan External Trade Organization (JETRO)[10] in 2008, reused water production costs are about one third of desalinated water production costs. Also, input electricity costs amount to one third of those necessary to run a *Reverse Osmosis (RO*) seawater desalination facility. However, the study correctly pointed out that in many facilities, especially in refineries or oil production sites, water is free of charge. This makes TSE uneconomic.

There are two fundamental factors that obstruct the path towards more use of TSE. The first, as already mentioned, is the pricing system of desalinated water that, through subsidies, does not encourage the search for more economic sources of water. The second problem is related to network and system capacity. Many investments have recently been made by GCC countries to increase the collection pipelines (to maximize the collection of wastewater) and to upgrade the redistribution networks (that transports treated water to consumers), but the current system still leads to the under exploitation of wastewater, of which, on average, only 50% is treated and reused.

Desalinated water has therefore been chosen as the main alternative to groundwater, with major consequences and spillover effects on the power systems of the GCC countries.

BOX 1. DESALINATION TECHNOLOGIES[11]

Desalination is the process that allows the removal of salt and other minerals from seawater, brine and brackish waters. There are two types of desalination technologies: thermal technologies and membrane filtration.

Thermal Desalination: thermal desalination involves distillation processes where saline feed-water is heated to vaporize, causing fresh water to evaporate and leaving behind a highly saline solution, namely the brine. Freshwater is then obtained from vapor cooling and condensation.[12]

The most common technologies are Multi Stage Flash (MSF) and Multi Effect Distillation (MED).

Multiple effect technology is based on thermal desalination. The main difference between MED and MSF is the method of evaporation and heat transfer. 'In MED plants, evaporation is from a seawater film in contact with the heat transfer surface, whereas in MSF plants only convective heating of seawater occurs within the tubes and evaporation is from a flow of brine 'flashing' in consecutive stages to produce vapor'.[13] MED plants are generally more efficient

10. Japan External Trade Organization, 'The Study on Wastewater Treatment and Water Reuse in Saudi-Aramco, Saudi Arabia' (Tokyo, 2009) 7-8.

11. IRENA (2015) 58.

12. ETSAP, IRENA, 'Water Desalination Using Renewable Energy', Technology Brief (Abu Dhabi, 2012), p3.

13. Corrado Sommariva, 'Desalination and advanced water treatment' (Baban Desalination Publications, 2010), p5.

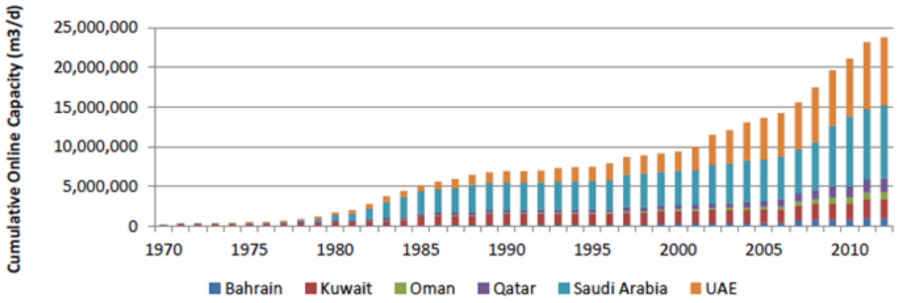
in terms of energy use, as this allows the feed-water to be processed without the need to supply additional heat for vaporization at each stage, and water quality is ensured by the separation between seawater and the vapor. However, both technologies can be coupled with power generation, using by-product heat. Co-generation of power, heat and water is therefore a highly efficient solution that has been often adopted in GCC countries.

Membrane desalination: These technologies use membranes to separate fresh water from saline feed-water. Feed-water is brought to the surface of a membrane, which selectively passes water and excludes salts. Reverse Osmosis (RO) is the most used membrane desalination technology. It requires electricity input to provide the pressure movement of the water through the membrane but no other fuel is required. RO plants cannot generate electricity.

Desalinated water, the most viable – but also energy intensive – option

Desalination techniques have been adopted in the Gulf region since the 1970s. Their steady increase is the result of contextual cheap energy and economic growth at that time. Oil-rich Saudi Arabia and the UAE have the largest relative desalination capacities (Figure 2), due to very high water consumption per capita (estimated around 350 and 550 liters per capita per day respectively). Generally, Multi Stage Flash (MSF) and Multi Effect Distillation (MED) thermal technologies represent 70% of the installed desalination capacity in the GCC countries, while the remaining capacity is Reverse Osmosis (RO).

Figure 2 Cumulative desalination capacities in the GCC countries, 1970-2012



Source: Saif (2012).[14]

The problem with desalination is that it requires considerable amounts of energy (either primary, such as fuel, or secondary, like heat or electricity), especially with thermal technologies (Figure 3). 'Seawater desalination via MSF consumes typically 80.6 kWh of heat energy (290 MJ thermal energy per kg) plus 2.5 to 3.5 kWh of electricity per cubic meter of water, while large scale RO requires only about 3.5 to 5.0 kWh of electricity per cubic meter.'[15] Currently, the global production of about 65.2 mcm per day of desalinated water involves the use of at least 75.2 TWh per year, i.e. 0.4% of the global electricity consumption. The production cost of desalination has been decreasing over the last years down to USD 0.5 per cubic meter, while market prices for desalinated water are typically between USD 1 – 2 per cubic meter (net of transport and distribution costs). Seawater desalination in the GCC is thought to account for 10-25% of total energy consumption,[16] although figures cannot be precisely

14. Omar Saif, 'The Future Outlook of Desalination in the Gulf: Challenges & opportunities faced by the UAE and Qatar' (2012) 5.

15. ETSAP, IRENA (2012) 3.

16.GCC to set up common water grid' (Emirates 24-7, 30 September 2013) www.emirates247.com.

calculated since many desalination plants are coupled with power generation.

The choice of desalination technologies and their efficient use in cogeneration differ from one country to another. As Table 2 shows, water desalination in Saudi Arabia and the UAE comes primarily from cogeneration plants. However, Saudi Arabia only produces a small part of its electricity by cogeneration. The Kingdom eventually plans to increase the electricity produced by these desalination plants equal to half of their current total output.[17]

As already mentioned, the UAE has a different power-water configuration, having the majority of their electricity produced by 24 cogeneration MSF or MED plants, with few stand-alone power generation plants and 14 RO desalination technology plants. The majority of water production therefore comes in combination with electricity generation.

Table 2 Water Desalination and Electricity capacity in the GCC countries in Mcm/y and MW/year

COUNTRY	WATER DESALINATION CAPACITY (MCM)	ELECTRICITY CAPACITY (MW)
Bahrain	**217 (2014)**	**2990 (2014)**
Kuwait	**702 (2010)18**	**6074 (2009)**
Oman	**323 (2014)**	**3280 (2014)**
Qatar	**358 (2008)**	**8755 (2013)**
Saudi Arabia	**1868 (2014)** **Cogeneration 87%** **RO 11%** **Thermal only 2%**	**26300 (2013)** **Cogeneration10.6%**
UAE (Abu Dhabi + Dubai)	**1790 (2012)** **RO 14.2%**	**23545 (2009)** **cogeneration 92%**

Source: ADWEC, DEWA, SCAD, NWC, Water and Electricity Authority Bahrain, Kahramaa, Ministry of Electricity and Water Kuwait, AQUASTAT, Arab News, IEA.

This is also the case for Qatar, whose largest desalination plants are coupled with power generation. In terms of fuel consumption, combined power and desalination water plants used the equivalent of 349 billion cubic feet of natural gas in 2010. Around

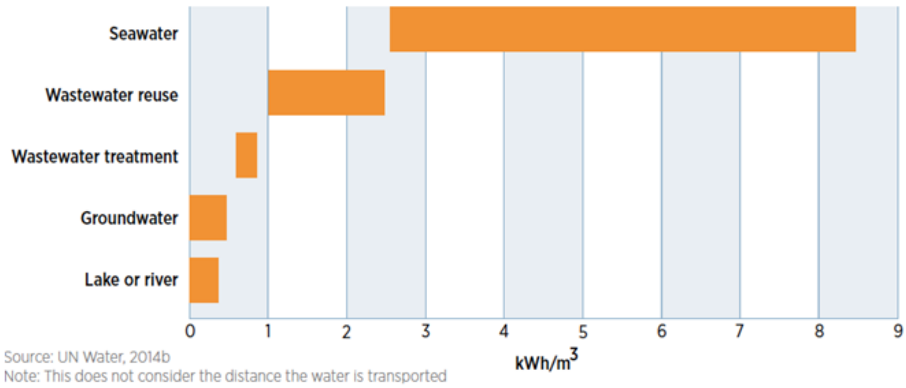
17.Royal Embassy of Saudi Arabia Washington D.C., <www.saudiembassy.net/about/country-information/energy/electricity> accessed 22 February 2015.

18. Arab News, 'Kuwait invests $5.28bn in water projects', 26 August 2013.

11% of the Qatari natural gas national production is therefore consumed for water and electricity generation.[19]

While Oman has more renewable water resources thanks to mountains and higher rainfall levels, it is similar to Bahrain and Kuwait in obtaining a substantial part of its domestic water consumption from desalination (85% of tap water). Both Bahrain and Oman have three cogeneration power and water plants, producing the majority of electricity and water.

Figure 3 General comparison of the amount of energy required to produce 1 cubic meter of water safe for human consumption, from different sources



Source: IRENA (2015).

The strong link between power generation and water production is at the heart of the water-energy nexus. Unless residential consumption stops increasing, more desalination, and therefore more energy, will be required. This will entail the consumption of more precious fossil fuel resources. Though GCC countries represent one third of world total proven oil reserves[20] and one fourth of total world oil production, the high use of oil and gas in their power mix[21] will eventually limit their export capacity and require massive investments or imports. Saudi Arabia has already banned the export of gas in order to continue providing cheap gas[22] to its economy, while the UAE has experienced gas shortages and has therefore started to import LNG, so has Kuwait.

19. M.A. Darwish & Rabi Mohtar, Qatar water challenges, 'Desalination and Water Treatment', DOI:10.1080/19443994.2012.693582 (2012) 7-8.

20. BP Statistical Review of World Energy June 2013.

21. Maïté de Boncourt (2012) 12.

22. *Ibid,* 28.

Governance, regulations and policy shifts to ensure supply security

The trends shown above send alarming signals about future water and energy requirements, with imminent security of water supply issues likely to hamper the growth in the economies of the GCC. For these reasons, governments have prompted several solutions on the supply side, launching ambitious initiatives. The latter probably will not be enough and significant reforms of the subsidy systems will be necessary. Also regional cooperation could pave the way for more socially acceptable reforms.

Energy to water and water to energy

In order to diminish fossil fuel consumption, the **diversification of energy sources** is one of the most sought after solutions, in particular through the introduction of nuclear and, to a lesser extent, renewable power plants. To reduce the energy to water nexus, the feasibility of renewable desalination is considered, in order to adapt renewable production to desalination techniques.[23] The economics of renewable desalination depends mainly on the cost of renewable energies, as the cost of desalination is largely determined by energy prices.[24] In some cases, such as the UAE, the introduction of new sources of electricity will require the decoupling of the water and electricity production systems. It will therefore entail an orientation towards RO techniques, necessitating only electricity input. The technological choice is therefore a discriminating factor in the future energy and water mix of the GCC systems.

This can especially be seen in the UAE, which is committed to nuclear power to satisfy growing power needs with low carbon technology. Saudi Arabia is also seeking to turn to nuclear power to meet its growing energy needs. Of course, the development of a civil nuclear program faces risks in a tense geopolitical environment such as the Middle East, in particular concerning uranium supplies. The huge investments needed are however compatible with the high revenues of these two oil countries. This is not the case for the other countries in the region, which are more penalized by current very low oil prices (in particular Oman), or which entered the race too late

23. Masdar, a subsidiary of Abu Dhabi Mubadala investment company, is experimenting four desalination technologies that will be coupled with solar energy (www. masdar.ae).

24. ETSAP, IRENA (2012) 3.

(Qatar).[25] Solar technologies, in particular concentrated solar power (CSP), seem to be another reliable option.

However, these two technologies – nuclear and CSP – do not improve the water to energy balance. On the contrary, CSP and nuclear generation are the most water consuming technologies for power generation.[26] CSP is a thermal production and needs cooling systems. A study by IRENA has nevertheless shown that if the GCC countries actually implemented their solar plans and respected the announced targets, a total reduction between 20% and 22% of water withdrawals and consumption could be reached in the power sector. This amount corresponds to 18 bcm of water withdrawal and 220 mcm of water consumption, i.e. 12% of UAE water desalinated production in 2012. The biggest savings would come from Saudi Arabia shifting from oil power plants to renewable or nuclear, as oil production requires significant amounts of water for extraction.

If a more balanced power mix combining power and water cogeneration with other forms of electricity production is sought, then there is a need to establish a clear roadmap. With more innovative desalination solutions and a greater flexibility, all actors of the value chain should be consulted in order to identify the risks and the spillover effects of each planned step. In particular, transmission system operators are concerned by technology choice and location. The Abu Dhabi case detailed in Chapter 2 shows that the diversification of electricity generation via nuclear energy can lead to an inefficient use of both nuclear and gas fired power plants, as the generation of water relies entirely on cogeneration plants. Also, despite the fact that water consumption has already reached the maximum current installed production capacity, the Abu Dhabi government has not yet planned new desalination capacity, as it hopes that new, higher water tariffs will lead to lower domestic consumption. TRANSCO, the transmission system operator, is however concerned by the reliability of the entire system, as higher demand would jeopardize the system.[27]

However, three reforms will be necessary to slow down the current race to water resources: a unified governance of water, overall water regulation and the end of subsidies.

25. Qatar Today, 'The Middle East's nuclear dream: far from reality?' January 19, 2014, accessed January 30, 2015, <http://www.qatartodayonline.com/the-middle-easts-nuclear-dream-far-from-reality/>.

26. IRENA (2015) 69.

27. Interview by the author with the Director of Assets Management at TRANSCO.

Governance

The definition of water resources into groundwater, desalinated and wastewater has usually led in the GCC countries to a typical separation of water management across different Ministries or Institutions: desalinated water (Ministry of Water and Electricity), groundwater (Ministry of Agriculture) and treated water (sometimes under the Ministry of Water and Electricity). Kuwait and Saudi Arabia are the only countries which have brought together all the activities related to water, under the supervision of one ministry. The overlapping of institutions and the separation of the types of water has led to incoherent policies, with a general misuse of water resources.[28] The powerful Ministries of Petroleum will probably be challenged by their Water and Electricity counterparts, as the example of Abu Dhabi has shown recently. After a consultation on the priority of gas dispatching in a situation of domestic gas shortfalls between the Abu Dhabi Water and Electricity Authority and the Abu Dhabi National Oil Company (ADNOC), ADNOC eventually accepted to supply the fuel to the Independent Water Power Producers (IWPP), and to reduce supplies for its program of enhanced oil recovery. These trade-offs will become more and more frequent if no alternative policies are put in place in order to stabilize or reduce domestic gas demand.

The change in market structure in electricity and water, from vertically integrated companies, to IWPPs has increased efficiency and lowered costs, but has not solved institutional weaknesses.

Regulation: for a comprehensive Water Law

Except for Saudi Arabia, which reformed its water system in 2001,[29] comprehensive Water Laws (managing all types of water) do not exist in the GCC states. Saudi Arabia has been at the forefront of governance and regulatory reforms, but still lacks enforcement capacity. In Qatar, a National Water Act is expected by 2016.[30] In the

28. In the case of KSA, the FAO report of 2009 clearly stated, "This lack of clarity of ministerial objectives and responsibilities and the presence of many players in the area of water resource management can lead to less effective planning, implementation delays, and increased costs. The existence of multiple staff at various agencies with similar skills precludes attaining a critical threshold for hiring not just technical staff but also staff trained in areas hitherto neglected such as pollution control, legal, economic, social science, and management. However, the establishment of the MOWE is a step towards streamlining water resources management in the country". FAO, 'Groundwater Management in Saudi Arabia, Draft Synthesis Report' (Rome, 2009), p.9

29. 'Nomination Of Ministry of Water & Electricity Kingdom of Saudi Arabia supporting document for King Hassan II Great World Water Prize 2012', p.38, www.wordlwatercouncil.org accessed 10 December 2014.

30. Available at: <www.theedge.me/qatars-fresh-water-challenges/> accessed January 20, 2015.

UAE, a federal Water Law is not compatible with the constitution, which leaves each Emirate with the right to administer and regulate its own natural resources. In this way, each Emirate has exclusive prerogative over its resources (water, oil and gas), and no binding federal tariff or legal framework seems legally applicable. This constitutional requirement hampers a more efficient management of water resources among the seven Emirates.[31]

Ending subsidies and lower consumption

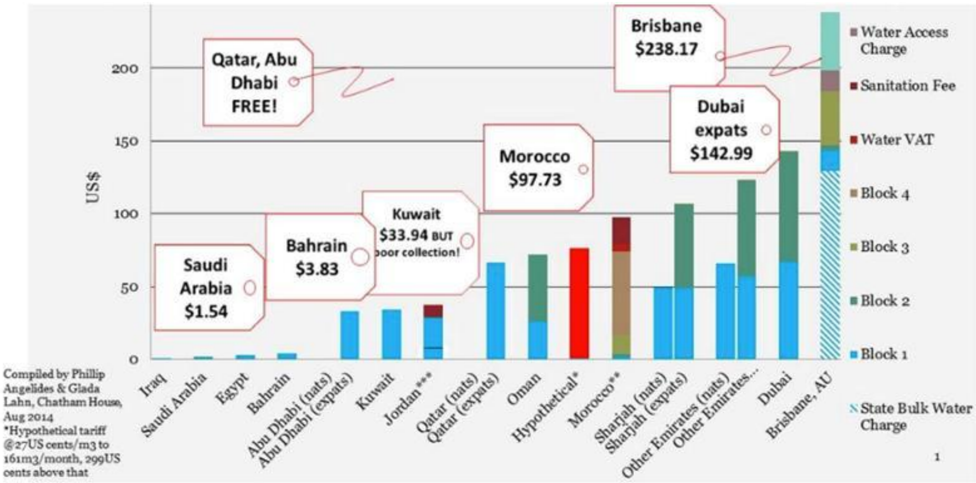
The biggest concern remains the high level of water consumption in the agriculture sector and the future increases in residential consumption driven by population growth. Sensitive trade-offs between food security and social peace could be brought to the attention of authorities. Also, high consumption and low prices affect the oil and gas sectors' ability to continue financing the systems. A trade-off between social acceptability and oil and gas export capacity should be avoided. In the case of Saudi Arabia, the ban on gas exports shows coherence in Saudi Arabia's willingness to rely on its own domestic resources. But it collides with the long-term perspective of scarce water resources and low revenues.

"There is no pricing for water for agricultural purposes. Once a borehole has been drilled, the owner has the right to produce water at his own cost with no tariffs being collected by the water authorities."[32] This statement, coming from Food and Agriculture Organization (FAO) assessing the water system in Saudi Arabia, could be easily extended to each GCC country. In addition, subsidies to residential consumption (domestic, government and industrial) are also a common practice among the GCC countries.

31.The seminar conducted by the Paris Sorbonne University in Abu Dhabi at the International Water Summit helped identify key aspects that a Water Law should include. Jacques Sironneau, the leading expert in water regulation at the French Minister of Environment, presented the main elements during the seminar and they will be published by the Emirates Center for Strategic Studies.

32. FAO (2009) p9.

Figure 4 Comparison of monthly water bills for high consuming household[33]



Source: Chatham House (2014).[34]

Figure 4 shows an approximation of water bills for a household of six people, each consuming 300 liters of water per day. In countries such as Germany or France, per capita consumption is around 100-120 liters. The most striking elements that result from this comparison are that in oil or gas-rich countries (Saudi Arabia, Qatar, Abu Dhabi in the UAE), water is supplied for free, or at a very low price and has created wasteful consumption habits.

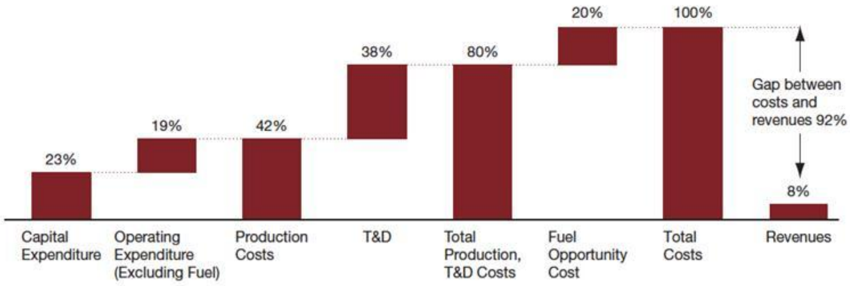
In general, expatriates pay a higher tariff than nationals, who pay a very low tariff or no tariff at all. In Abu Dhabi, for example, nationals started paying water since January 1st, 2015, but at a much lower tariff than expatriates, who saw their tariffs triple. In some cases, water tariffs increase with consumption. In Bahrain, tariffs have progressed since 2007, but they are still very low. For instance, the first tariff block (0-6000 cubic meters) is USD 2.65 per cubic meter of water consumption. The differences between the consumer prices and actual costs are borne by governments and so are subsidies. Sometimes, these can represent 90% of the total costs (Figure 5).

---

33. A household using 55 cubic meters per month is defined as a 'high consuming household' by Chatham House.

34. Glan Lahn, 'Counting the Cost of Water Resources in the GCC Countries: A Nexus Perspective' (WSTA 11th Gulf Water Conference, Muscat, October 2014) p.8.

Figure 5 Break down of total water costs (production, transmission and distribution) and revenues



Source: Strategy& (2014). N.B.: 'T&D' stands for Transport and Distribution.

Furthermore, the overall real costs are actually higher than what it is sometimes publicly communicated by national authorities, as they do not include the heavy subsidies on the electricity tariffs or fuels. For instance, in Abu Dhabi, in addition to the AED 4 billion[35] in subsidies to the residential sector, low natural gas and diesel prices also need to be taken into account. Sometimes, power and water purchase contracts are stipulated with nominal prices, thus preventing the adjustment to inflation. In addition, the sector is vertically integrated and only partially liberalized. National oil and gas companies often provide the fuel whose purchase transactions do not appear on balance sheets. The privatization of the water desalination projects, which started in Oman and in the UAE (Abu Dhabi) in the early 2000s, did contribute, however, to overall cost reductions. Also, this type of system has provided stability and predictability so far. It is not certain that a deeper liberalization and unbundling reform would lower overall costs and subsidies.

However, removing subsidies is not an easy task for two main reasons:

First, increasing prices in fuels, water or electricity may not produce an immediate or a significant result as hoped. The elasticity of energy and water has proven to be very low in GCC countries where GDP per capita is among the highest in the world. Furthermore, this action might entail social unrest, threatening these countries' stability, especially in a tense geopolitical environment with an ungoverned Libya, a civil war in Syria and mounting pressure on nuclear talks in Iran. When the so-called 'Arab springs' began, GCC governments quickly calmed their own internal dissension by

35. Author's calculations based on reports by the Statistical Center Abu Dhabi for 2006, 2007, 2008, 2009, and ADDC tariffs.

increasing government wages and tightening control over mosques and associations.[36]

Second, a rise in tariffs could be socially acceptable and more easily applied if all GCC countries take the action in a coordinated way. Despite many initiatives for the creation of a common electricity market and other commercial joint initiatives, numerous obstacles hamper any further efficient co-operation in water management, in particular the existence of subsidies in the water and electricity sector.

The possibilities of regional cooperation

Some GCC countries already share water basins. In particular, Saudi Arabia shares aquifers with other countries around it. It is estimated that 112 mcm per year flow from aquifers in Saudi Arabia to Bahrain, 20 mcm per year flow to Kuwait, and 2 mcm per year flow to Qatar.[37] Also water from Omani mountains helps to recharge oasis groundwater at Al Ain, UAE. However, despite the announcement of several initiatives at GCC level to tackle these common problems in a coordinated way, structured cooperation has not yet been established.

GCC water pipeline

An attempt to create a common initiative is the GCC water pipeline project. It connects RO plants on the Gulf of Oman, through the UAE, to the other four GCC countries.[38] With an estimated USD 10.5 billion budget, the project develops in three stages. The first, which aims at the creation of a pipeline network linking the six countries, will cost around USD 2.7 billion. The second and third phases will cost nearly USD 7.8 billion to build two plants in Oman’s coastline.

However, a GCC wide pipeline raises some issues. Water infrastructure is difficult to build and is very expensive. National systems already have leakages of 30%, and need remote monitoring. Though Saudi Arabia has constructed very long-range water pipelines to connect Jeddah desalination plants to Riyadh, a trans-GCC pipeline seems a hasty move, rather than being a long-term cost-efficient strategy.

36. ‘Oil makes reforms urgent’, The National, March 6, 2015.

37. FAO, ‘Groundwater Management in Saudi Arabia, Draft Synthesis Report’ p.10

38. ‘GCC to set up common water grid’ (Emirates 24-7, published Monday, September 30, 2013) www.emirates247.com

Also, connecting the water systems raises the question of water pricing. If the water produced by the two plants in Oman is sold independently from other national water sources, the contract agreement should not encounter financial or social problems. If the aim, however, is to connect the six countries' national water systems, then concerns on price and subsidies will probably hamper the process. Since prices are subsidized and internal markets are not open to competition (the price of water or electricity is not determined by the equilibrium of supply and demand), it would be difficult to find an agreement on the optimal price.

As already pointed out by many experts, the connection of the water systems would lead to the same issues concerning common electricity systems.[39] The citizens of the countries with the highest subsidies (Saudi Arabia) would pay for cheap electricity provided to neighboring countries through interconnections. This, in turn, affects the price of desalinated water, which receives subsidies in three ways: fuel, electricity and final consumer tariffs. In addition, some countries, such as the UAE, are accelerating their ambitious 2030 energy roadmaps, in order to be the first one to produce nuclear and solar electricity. This leadership would provide them with enough power capacity to export electricity to neighboring countries, with interesting commercial prospects. The UAE, and in particular Abu Dhabi, could be net exporters of energy to neighboring countries that have not promoted enough reforms or enhanced their power and water systems.

A common framework for water and electricity tariffs as a way forward

The only way GCC countries will be able to work together and set a common effective framework on water is to unify strategies and raise the price of water altogether. In the UAE, there are already some forms of water cooperation through water transfers between Emirates, notably to Fujairah, that lacks sufficient production. In 2012, the use of water in Sharjah, and in the Emirates of Ajman, Umm Al Quain, Ras Al Khaimah and Fujairah, was higher than their domestic production. Water was therefore provided from the Abu Dhabi Water & Electricity Authority.[40]

One form of water trade across borders could rely on actual production costs without subsidies, or on an agreed formula to calculate prices. This would therefore require agreeing first on the fuel costs, by considering either the costs by fuel (based on international

39. In particular, see Keith Miller 'The Prospects for Electricity Trade Between the GCC Countries' (MEED 2nd Middle East Power and Water, Abu Dhabi, March 2005) and Maïté de Boncourt, (2012).

40. United Arab Emirates, National Bureau of Statistics (2007-2012).

oil and gas prices or fiscal budget breakeven prices),[41] or overall fuel costs (when nuclear plants will start operating in Abu Dhabi). Then, capacity and transport costs would need to be agreed on. Another form of cooperation could be 'water markets' or 'water banks'. The use of 'water banks' has arisen in times of extreme drought, and has been developed in the United States. Currently, an interstate water bank initiative links Arizona, California and Nevada.[42] A 'water budget' is also under study in Abu Dhabi.[43]

The next chapter will analyze in more depth the challenges encountered by the Abu Dhabi Emirate and the solutions that its government is seeking. These may provide some interesting pointers for other Emirates and GCC countries.

41. For a definition of a breakeven budget price see Maïté de Boncourt, ''Energy Strategy of the GCC countries'' (2012) p10.

42. Piotr Szwedo, ''Water trade as an alternative for Abu Dhabi? Legal analysis'' (International Water Summit, Abu Dhabi, 2015) p8.

43. EAD, 'Abu Dhabi adopts innovative water budget approach', press release (January 2015) <www.ead.ae/presscentre/>

Abu Dhabi's Water Strategy as a Case Study

As in all the GCC countries, water consumption in Abu Dhabi has increased steadily in the last five years. H.H. General Sheikh Mohammed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi has stated: "Water is more important than oil for the UAE. We are preoccupied by this major issue. I believe the problem lies in the fact that the population of the Arabian Peninsula is incessantly growing while the region today does not possess a lot of resources."[44]

This statement shows the acute awareness of Abu Dhabi's rulers about their water status. Since the 1970s, they have been setting up strategies to capitalize on their oil resources as best as possible in order to ensure intergenerational equity. The Abu Dhabi Investment Authority[45] has assets running to an estimated USD 770 billion, reassuring the ruling family of secure financial back-up even in the event of falling oil prices.[46] Also, the diversification of the economy via tourism and industry has helped hedge the reliance on oil production, while refining activity has added value to pure crude exports. Non-oil economic activities experienced stable growth during the period 2007-2012, and raised their contribution to the real GDP from 44% in 2007 to 48% in 2012.[47] However, the most important legacy for future generations will be water resources.

The key questions policy-makers are trying to address are related to how to preserve and protect these strategic water resources. As great amounts of energy are required to produce water in Abu Dhabi, it is essential to choose the right balance of energy mix and water production technology in order to meet the demand, while

---

44. H.H. General Sheikh Mohammed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi, Deputy Supreme commander of the UAE Armed Forces, and chairman of the Abu Dhabi Executive council at Al Bateen held in Abu Dhabi on December 2011.

45. ADIA is the Abu Dhabi Investment Authority created in 1976 to manage the Emirate's oil revenues. It does not disclose the annual performance of its assets (www.adia.ae). John Everington, 'Adia reaffirms commitment to emerging markets' (The National, July 1st 2014) <www.thenational.ae>

46. MEES, 'UAE :oil price will not hit expansion', (Beirut, 2014) Vol.57, No 46.

47. Department of Economic Development, Economic Report of the Emirate of Abu Dhabi, (Abu Dhabi 2013) p3.

protecting the environment and reducing the consumption of high-value fossil fuels.

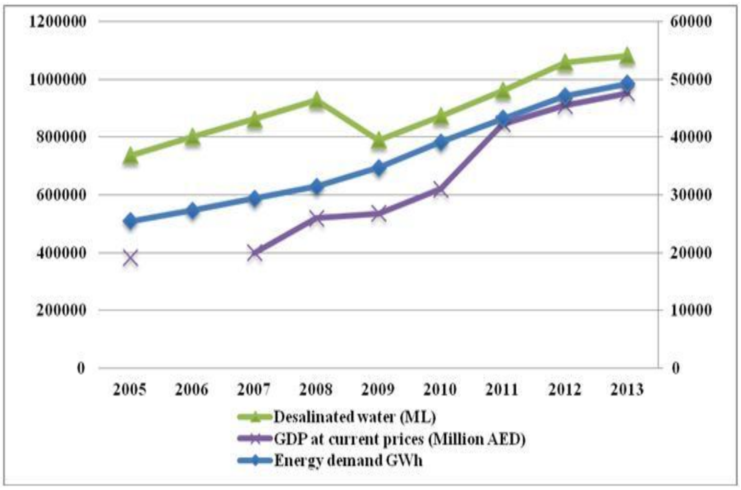
While strict economic optimization has not been the primary element of water strategies in the past, the burden of subsidies and the dependence on gas resources have shown the limits of the current system. Growing dependency on Qatari gas, in an unstable political environment since the Arab spring, following the 2008 economic crisis, have shown that diversification of supplies and revenues is the best strategy to adopt for the future management of water and energy. This will come at a cost.

This chapter analyses the relation of water and energy consumptions with GDP and population growth in Abu Dhabi. A rapid overview of the sector's organization, combined with an analysis of the strategies adopted by the Abu Dhabi government, also allow the government's answers to the key challenges to be examined.

The global picture of the water sector in Abu Dhabi

There is a strong connection between GDP growth (Figure 6), water and electricity consumption. In the past ten years, Abu Dhabi's GDP increased threefold, desalination water production rose by 50% and electricity production doubled. The population of the Abu Dhabi Emirate increased by 75% in less than ten years, from 809,000 to 1,418,200 people.[48]

Figure 6 Correlation among electricity consumption, economic growth and water demand (energy values on the right axis of the graph)



Source: SCAD Statistical Yearbook 2007, 2009, 2010, 2011, and 2014.

48. Statistics Centre Abu Dhabi, 'Statistical Yearbook Abu Dhabi 2013'.

Despite the economic diversification, oil and gas production remains the main source of government revenues, accounting for 93% of the total revenues in 2013. The Abu Dhabi Government thus relies on the oil rent for its generous public policies. The subsidies policy in the water sector notably reflects the Government's willingness to keep end-consumer prices low and can be largely assumed by the oil incomes.

The current Abu Dhabi water system: production and consumption[49]

Abu Dhabi together with Dubai consumes 86% of total UAE fresh water. Daily-consumed fresh water comes primarily from three sources: groundwater, desalination plants and treated sewage water.

- **Groundwater** is still the primary source of consumption in Abu Dhabi (Figure 7). In 2013, it supplied 67% of the total water production, while 29% was desalinated water and 4% treated sewage water.[50] Groundwater reserves are estimated to be 635,620 mcm (2011).[51] However, only 3% out of the total resources is considered fresh water; 18% is brackish and 79% is saline. This means that only 21% of Abu Dhabi resources can be used, while the rest needs desalination. In France, as a comparison, 2000 bcm of reserves[52] can be replenished by 867 mm of rainfall per year.[53] Precipitation in Abu Dhabi is limited to 78 mm per year.[54] Given the consumption rate of the last decade, groundwater renewal cannot be ensured.

49. The availability of fresh water consumption and production data is subject to estimates as different sources contribute to the water system. While desalination water can be easily metered at the production plant or from the final consumers' meters, groundwater and reused water are more difficult to assess. Furthermore, leakages in the network can be as high as 30%. It is therefore with much precaution that figures have to be handled.

50. Total water production in 2013 was 3,613 mcm, of which 2,414 mcm from groundwater, 1,060 mcm from desalination plants, 139 mcm from recycled water (SCAD 'Statistical Yearbook 2013').

51. SCAD 'Statistical Yearbook 2012'.

52. Raphaël Demouliere, Joy Bensaid Schemba, Joshua Berger, Ahmed Aït Kaci, Fanny Rougier, 'Public water supply and sanitation services in France Economic, social and environmental data', *Les entreprises de l'eau*, (BIPE 2012), p7.

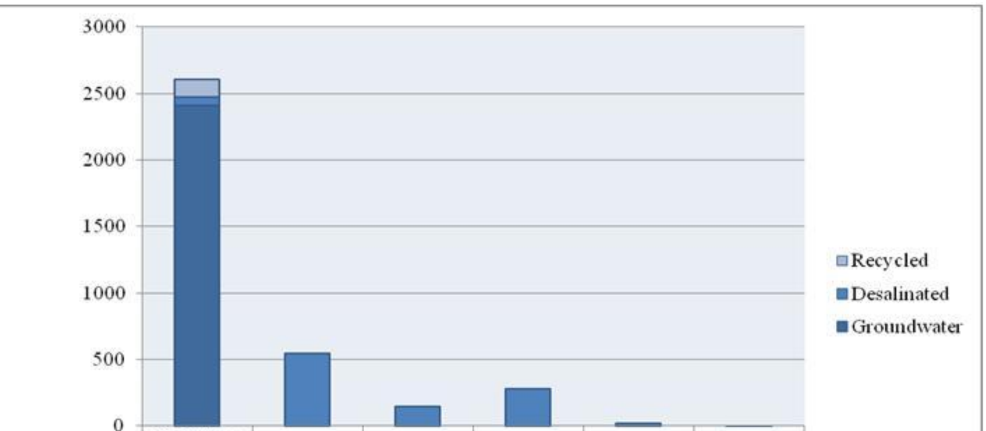
53.Banque Mondiale, 'Hauteur moyenne des précipitations (mm par an)', http://donnees.banquemondiale.org/indicateur/AG.LND.PRCP.MM accessed January 5, 2015

54. *Ibid*.

'Abstraction rates exceed 25 times the average groundwater recharge rate', which means that '(…) at current consumption patterns groundwater will be depleted' by 2050, affirms the Environment Agency of Abu Dhabi (EAD).[55] Furthermore, this also affects its quality as salinity is rapidly increasing. At this pace, all the groundwater will become saline soon.

Agriculture is the most important sector consuming water resources, in particular of groundwater (93% of total agriculture water consumption comes from groundwater). According to the Abu Dhabi Statistics Center (SCAD), agriculture accounted for half of the total water demand in 2012, while forests and public parks consumed 20% of all fresh water. The EAD estimates that 'demand for irrigation seems to be decreasing steadily (7% in the period 2009-2011), very likely due to the adoption of demand side management measures to encourage a more efficient use of water by farms.'[56] This trend will help to lower the pressure on other types of resources, such as desalinated water, which will likely substitute groundwater when it will become too saline to be treated locally.[57]

Figure 7 Water consumption by sector and type of water, 2012, in mcm



	Agriculture, forests and parks	Domestic	Commercial	Government	Industry	Other
Recycled	138,8	0	0	0	0	0
Desalinated	57,2	548,68	145,12	280,7	18,01	10,59
Groundwater	2413,9	0	0	0	0	0

Source: SCAD Statistical Yearbook 2013, EAD.

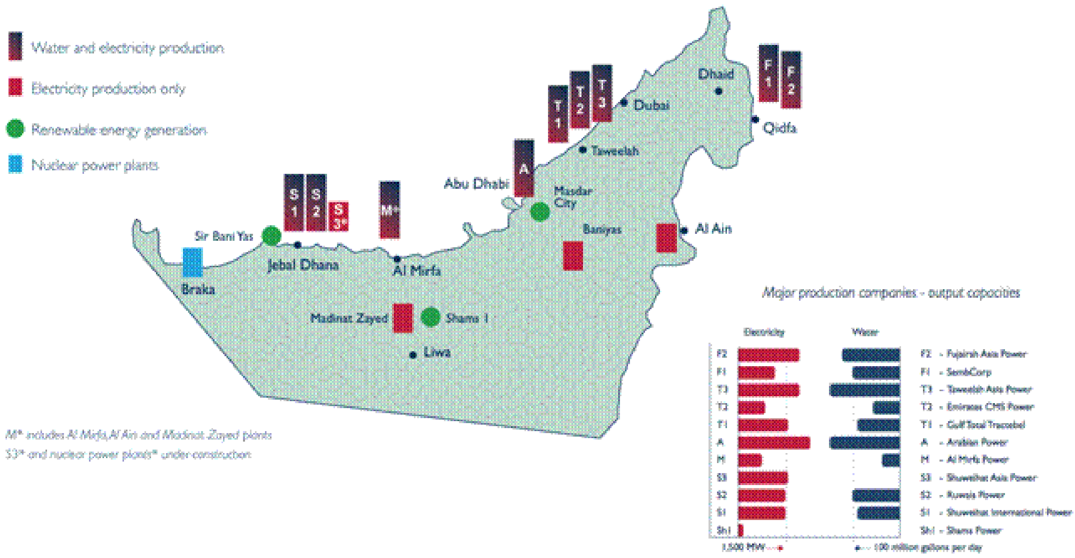
55. EAD, 'Advancing sustainable groundwater management in Abu Dhabi', (Abu Dhabi, 2012), p3.

56. *Ibid.*

57. The agriculture sector adopted local reverse osmosis plants fuelled by solar panels.

- **Drinking water for domestic consumption (residential, commercial and government sector)** comes exclusively from desalination plants. Most of the plants use co-generation Multi Flash Stage technology or Multiple Effect Distillation, while only two plants are using the RO technology,[58] which accounts for 7.4% of the total water production. To cope with increasing demand, between 1999 and 2012, the total annual production increased from 70,917 million imperial gallons (MIG) to 253,190 MIG, a rise of **about 257% or at an annual growth rate of 10.3%**.[59]

Figure 8 Map of the major water and electricity production companies, 2012



Source: Regulation and Supervision Bureau, Water and Electricity Sector Overview 2010-2013.

- **Recycled water** is still largely underused. Out of the total recycled water, around 50% is actually reused. Recycled capacity sharply increased in 2010, from 183 mcm to more than 400 mcm per year.[60] It more than doubled in

58. In Reverse Osmosis, to separate fresh water from seawater, the membrane acts as a barrier between two phases that allows for preferential and selective crossing. Pressure is used to drive the water through different membranes. (Sommariva) RO plants cannot generate electricity, they consume electricity for the pressure process. See Box 1 in Chapter 1.

59. TRANSCO, '2013 Seven Year Water Planning Statement (2014-2020)', (Abu Dhabi, 2014).

60. SCAD Statistical Yearbook 2007, 2009, 2010, 2011, 2013.

only one year, thanks to the opening of new independent sewage treatment plants (ISTP). However, half of the treated effluents are discharged in the Arabian Gulf. Three main reasons are given for this by EAD:[61]

- The lack of transmission and distribution networks to supply customers (which are mainly forests and private companies such as golf resorts);

- 'Scattered ownership of the available infrastructure between Abu Dhabi Sewage and Services Company (ADSSC), responsible for the main transmitting recycled water, and Abu Dhabi Municipality's Parks and Recreational Facilities Department (PRFD) in charge of the other distribution networks'[62]

- Lower demand due to the 'financial downturn' of the last 5 years.

These views have been confirmed by the Director of a major independent treatment plant and by a government official,[63] who both added: 'technically all the treated sewage effluents could be redistributed for the irrigation of forests, crop fields or golf courses. The main obstacles come from the development of the distribution network and from cultural aspects: it will be difficult to convince consumers such as farmers to use recycled water'.

The current quality of recycled water is suitable for forests and parks, but studies are under way for its use in the agricultural sector. In fact, as only about 26% of desalinated water consumed returned to the sewerage system (2012 data),[64] intakes from industrially discharged water are responsible for pollution in sewage water. To produce water with a quality suitable for agricultural purposes, more treatment would be necessary, increasing the costs of treated water.[65]

61. EAD (2013) 6.

62. *Ibid.*

63. Abu Dhabi energy official interviewed on condition of anonymity.

64. 'The main reason behind this low rate of water returned to sewer is the high use of water outdoors, for the irrigation of gardens and parks, in swimming pools and for washing cars. Other reasons are technical and commercial losses.' EAD, *Ibid*. p.4

65. An expert of the treatment sector told the author, under the condition of anonymity, that because of the industrial intakes, zinc levels are very high. RSB (the regulator) still has to define if the levels are acceptable for agriculture irrigation. Also, recycled water costs are estimated to be AED 7 per 1000 litres, less than desalinated water, which is AED 10.43 per 1000 litres.

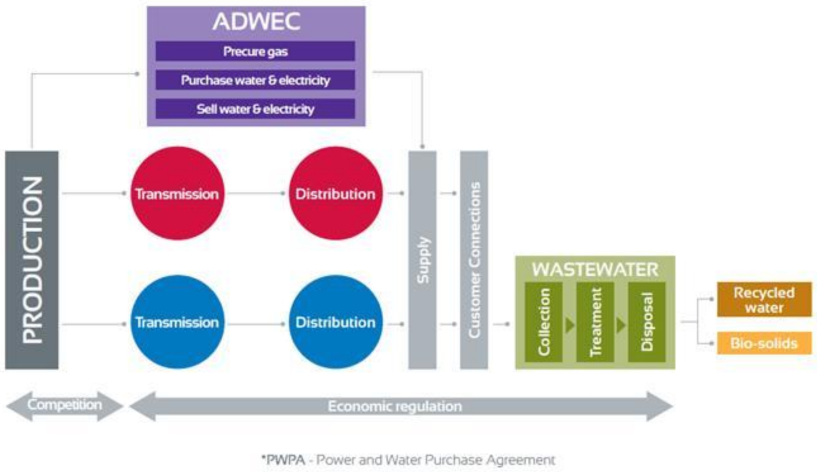
Governance and market structure

Water in Abu Dhabi is managed by type of production: groundwater, desalinated and recycled water. A Water Council, which is yet to be created, is expected to coordinate and set the strategy of the whole water sector,[66] while a 'three tap policy'[67] has been proposed and is under study by the Regulation and Supervision Bureau (RSB). Currently, for each type of water there are several actors that intervene on a strategic and operational level, as explained in Box 2.

The market structure is a typical single buyer model with partial liberalization on the production side.

Privatization of the water desalination production started in Abu Dhabi with large IWPs or Independent Water and Power Producers (IWPPs) projects in the early 2000s. These allowed foreign companies to create joint ventures with local national companies, which has contributed to diversifying technology and lowering production costs.

Figure 9 Market Structure of desalinated and recycled water as of 2012



Source: RSB Annual Economic Report 2013.

Although the vertically integrated company (ADWEA and its subsidiaries ADWEC, TRANSCO, ADDC, AADC) is the dominant operator, the Abu Dhabi water and electricity sector is based on transparent regulation and functioning. The Regulator publishes end-consumer water tariffs, while the single buyer (ADWEC) openly calculates the bulk supply tariff for distributors. Also, the system

66. EAD, '2009 Abu Dhabi Water Resources Master Plan', (Abu Dhabi, 2009), p.6.

67. The 'three-tap-policy' aims at an integrated management of the three sources of water.

shows stability and predictability, both of which are essential to setting a good business and investment climate. Although water prices are not freely set by supply and demand, they are based on recurrent asset evaluation, and, thanks to remuneration based mainly on capacity,[68] they provide good revenues to IWPP, whose earnings increase the lower the dispatch costs are.

However, the total costs of the system are becoming incredibly high. EAD estimates that 'subsidies of AED 217 billion (approximately €43 billion, n.d.a.) will be incurred over 20 years (assuming tariffs remain unchanged, and not accounting for inflation). If demand continues to increase at the current pace, subsidies will become a large fiscal burden for the government.'[69] In fact, if demand side policies or network improvements (aimed at diminishing leakages and increasing water re-use) are not implemented soon enough, new desalination capacity will be needed to meet higher demand and it will require large capital and fuel expenditures.

Fuelling water and electricity production

The actual costs of current water and electricity production have been made public by the RSB since 2012, as a measure to incentivize more rational consumption. Public awareness is one of the demand-side strategies put in place to deal with the future rising consumption of desalinated water: 'new electricity and water bills are one way to provide better visibility of power and water consumption, and influence long-term behavioral changes around the use of these resources.'[70]

The change in consumption patterns is a key component of the sustainable management of water resources, as it will affect desalination production costs and subsidies. It is also a means to lower fuel import dependency and increase energy security, as desalination plants are fuelled by large amounts of natural gas. At the same time, supply-side policies are implemented to optimize water and electricity production. These include the de-coupling of electricity and water production and the increase in the re-used water for agriculture.

68. Capacity remuneration is based on a water capacity charge that remunerates capital costs (investments, fixed operations and maintenance costs, etc.). It is therefore a fixed charge. In contrast, water output charges are based on the actual water produced and are proportional to volume. Capacity remuneration also recovers the variable costs and electricity (or energy) consumed in the process. Usually the tariff system is a combination of both charges. Source: C. Sommariva, Desalination and advanced water treatment, p.106

69. EAD (2012) p11.

70. Available at : http://rsb.gov.ae/en/sector/water-and-electricity-bills.

The costs of water production

To evaluate precisely the costs of the water sector, it is necessary to approach differently the three types of water production. While groundwater does not have a tariff, the numbers given in Figure 10 give a breakdown of the actual costs for desalinated and recycled water.[71] The RSB published its first Annual Economic Report[72] that provides a transparent analysis of costs and revenues of the electricity and water sector.

Figure 10 Turnover and overall costs

Source RSB Economic Report 2013

As shown in Figure 10, RSB estimates that in 2013 the water turnover [73] was AED 9.8 billion, AED 14.2 billion for electricity and AED 2.3 billion for wastewater.

71. A study by EAD is underway to calculate the cost of groundwater. Also, EAD has proposed analyzing the possibility of creating a 'Water budget', which is meant to set a cap on water consumption and to trade-off allocation among sectors.

72. RSB , 'Annual Economic Report 2013' (Abu Dhabi, 2014)

73. Turnover 'consists of revenue to cover production, transmission and distribution costs' *Ibid*. 4.

Figure 11 Production costs of water and electricity

Source RSB (2014).

These figures are of particular importance as the calculation of costs in Abu Dhabi water sector presents some difficulties.

In the Emirate of Abu Dhabi, there are 11 desalination plants, most of them with combined water and electricity cogeneration plants. While combination of power generation and water production is one of the most effective uses of steam and energy, it presents some disadvantages during wintertime. In fact, while water production remains constant, electricity consumption diminishes sharply due to cooler weather and a decrease in the use of air conditioning.[74] The demand curves then therefore take very different shapes.

Although the average costs of desalinated water production are mostly known, the use of cogeneration plants makes it difficult to split charges (in particular fuel ones) between water and electricity production. For example, the 2011 Bulk Supply Tariff (BST), which is the wholesale tariff paid by distribution companies for water and electricity supplied to them by ADWEC, equally divided fuel costs incurred by ADWEC between electricity and water.[75] Back-up fuel was also divided equally between water and electricity and in 2011 costs amounted to AED 4000 Million (€ 800 Million).[76] Since 2012, the calculation of BST has changed to include seasonality and peak differences with a 'system marginal price (SMP) charge' estimated to

74. Corrado Sommariva, Desalination and advanced water treatment (Baban Desalination Publications, 2010).

75. ADWEC, 'Bulk Supply Tariff 2011',(Abu Dhabi, 2011) 7

76. It has to be noted that fuel is provided to IWPP by ADWEC, but its costs do not appear on the balance sheet. In exchange, IWPP produces electricity.

indicate the short-term marginal costs (excluding back-up fuel (BUF) costs) of providing units at different times of the day.'[77] However, as Figure 11 shows, fuel costs are still equally attributed to water and electricity, while availability (capacity) and Operations &Maintenance charges differ. RSB admits 'the calculation of the BST is required to contend with the additional complexity of allocating fuel costs separately to water and electricity from cogeneration plants'.

Figure 12 Fuel allocation methods and variations

		'Summer' Case	most efficient point	'Winter' Case
	MW	1,350	1200	430
	MIGD	85	85	85
Power to Water Ratio	**MW/MIGD**	16	14	5
Reference Cycle Method	***Allocation to power***	70%	69%	45%
	Allocation to water	30%	31%	55%
Marginal Cost Method	***Allocation to power***	79%	69%	15%
	Allocation to water	21%	31%	85%

Source: ADWEC

Fuel cost allocation depends on the methodology applied.[78] A marginal cost[79] method seems to reflect better the differences between water and electricity fuel consumption in summer and winter months. Seasonality and peak hours are already included in electricity tariffs for big consumers connected to the transmission system.[80] For residential consumers, RSB's unit Powerwise is analyzing the possibility of introducing a seasonal and peak-hour tariff.[81] However, since water demand is more constant and peak hours can be handled by short-term storage, water tariffs have not been differentiated yet.[82]

77. RSB, 'Annual Economic Report 2013',1. And http://rsb.gov.ae/en/sector/tariffs-and-charges

78. Sandra B. Fischer, Fuel Cost Allocation in Cogeneration Production of Power and Water, MEED 3rd Middle East Power and Desalination 12th – 13th March 2006 Hilton Hotel, Abu Dhabi, UAE

79. 'Which means cost of last unit (MW or MIGD) produced' Ibid.

80. RSB, 'Statement on electricity and water costs 2013 – 2014', (2013) 2.

81. *Ibid.*

82. *Ibid.*

Finally, the revenues for the production companies (including IPPs, IWPPs and renewable energy producers) and ISTPs are determined by the prices that were obtained through competitive tendering and represent the main ‘availability costs’.

These prices are set out in the respective Power Water Purchasing Agreements and sewage treatment agreements between these companies and the off-taker (ADWEC or ADSSC). For each network company, annual turnover is capped by its Maximum Annual Revenue (MAR). This MAR allows each company to recover its efficient operating costs, depreciation and return on capital. It has to be noted that capacity charges are based on a fixed remuneration and are attributed based on the availability of the plant, and not on the actual production. Moreover, when the 25-year contracts are signed, the capacity charges and the profit are calculated based on the financial parameters (Libor, for example) of the contract stipulation year. Also, they are calculated in nominal and not real terms. Actual costs of water and electricity production should therefore be much higher.

Subsidies

The water and electricity sectors are largely subsidized. It is part of a public policy and it is openly addressed by regulators and policy makers. As RSB notes: ‘in recognition of the fact that the government of Abu Dhabi has historically subsidized the supply of water and electricity, the license for the distribution companies allows ADWEA to direct that certain customers are “subsidy customers”, and that such customers are charged a tariff determined by ADWEA. The difference between the total revenue that can be recovered by the distribution companies and the revenue they receive from customer tariffs represents the government subsidy to the sector.’ Based on the actual costs given by RSB, the author estimates that AED 4 billion were given by the Abu Dhabi government to ADWEC, to cover the subsidies for domestic sector water consumption in 2012.

For groundwater production, subsidies on operational costs are in the form of low electricity tariffs and can be calculated as the difference between the electricity tariffs for agriculture (3 fils/kWh), and the actual costs (24.1 fils/kWh). Subsidies are therefore 87% of the actual costs and they amounted to about AED 579 million for 2013.[83] Given that the annual public sector budget is AED 52 billion

83. Calculated by the author as the amount of electricity consumed by the agriculture sector, multiplied by the price of the subsidy.

for Abu Dhabi[84], the share of the water subsidies in spending alone is about 9%.

Although UAE ranks fifth and seventh in the world for proven oil and gas reserves, with a production of 2.9 million barrels of oil per day, and though overall costs seem still to be 'reasonable' in view of current desalinated production (with the difficulties and bias mentioned in real cost terms), there are structural problems hampering the water system. Ultimately these will lead to cost rises.

Non-economic issues at stakes: securing gas supplies and protecting the environment

Subsidies certainly represent an economic burden, but other concerns might play a more important role for the water management strategy. The over-consumption trend of the residential sector has led to one of the highest per capita consumption rates in the world: 614 liters per capita, per day in 2010. This has several geopolitical, environmental and social consequences.

- *Geopolitical issues: import dependency*

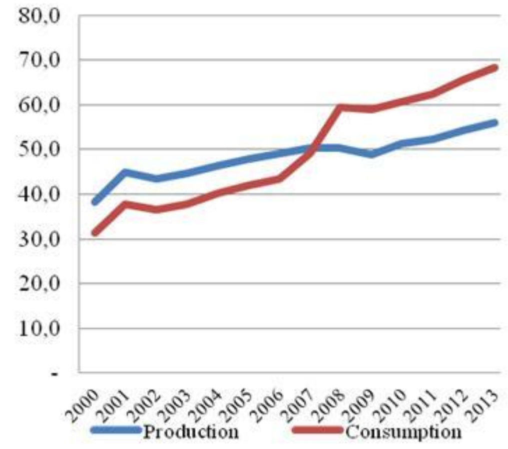
The UAE consumes gigantic quantities of gas: as much as Italy with 60 million inhabitants. As of 2007, the UAE became a net importer of gas, as its production could no longer cover its massive use (Figure 13). In fact, despite increasing natural gas production, large amounts are consumed by the oil sector, as natural gas is required 'for oil field re-injection to maintain reservoir pressure and oil production capacity from its largest oil fields as they mature.'[85] The competition among internal consumers (in particular oil recovery ADNOC activities and gas cogeneration plants) culminated in two shortfalls in 2005 and 2009. Crude oil and gas oil were then used to sustain electricity and water production (Table 3). The government of Abu Dhabi thus needs urgently to find new ways of producing water without requiring gas.

84. Author's calculations based on the contribution to federal government and SCAD statistics. The author could not find any available information on the current and past budgets.

85. UAE interact, 'Oil and gas', (UAE interact) accessed 14 January 2015.

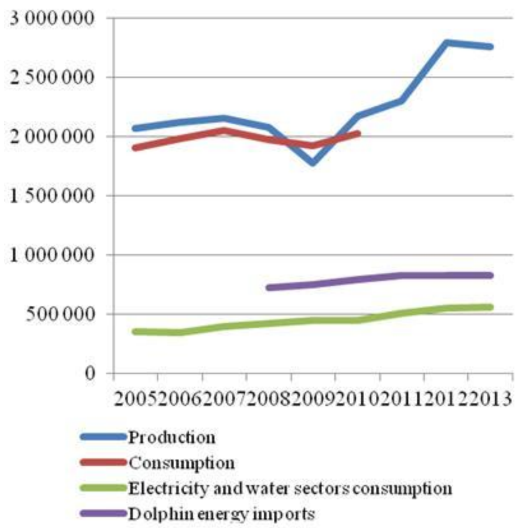
Figure 13 The natural gas sector in the UAE and Abu Dhabi

UAE GAS PRODUCTION AND CONSUMPTION 2000 – 2013, BILLION CUBIC METERS



Source: BP Statistical Review 2014.

ABU DHABI NATURAL GAS SECTOR 2005-2013, BILLION CUBIC FEET



Source: SCAD Yearbook 2009, 2010, 2012, 2013, 2014.

Imports from Qatar have closed the gap through the Dolphin pipeline. As of 2014, Qatar became the only supplier of natural gas. To diversify supplies, two LNG terminals, one in Dubai and one in Fujairah, are expected to cope with increasing consumption. LNG prices are higher than domestic prices ($3-7 MMbtu[86] and $2 MMbtu[87] respectively), and will likely increase the overall water and electricity bill.

---

86. 'World LNG Estimated June 2015 Landed Prices', www.ferc.org, accessed 25 May 2015.

87. Natural gas prices are not public. This information has been gathered through interviews with representatives of international oil companies and an adviser to the Abu Dhabi Executive Committee.

Table 3 Fuel consumption of the electricity and water activity in billion BTU

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total	372.8	405	430.2	486.8	483.6	502.5	543.6	574.7	588.8
Natural Gas	370.9	360	414	485.8	469.7	467.1	528.1	574.5	587.9
Crude Oil	1.2	27	10.7	78	7.8	21.9	6.1	0	0
Gas Oil	557	12	3	894	5.2	13.4	9.5	210	889
Fuel Oil	1	6	2.4	82	849	4	0	0	0

Source: SCAD Yearbook 2009, 2010, 2012, 2013, 2014

- *Environmental stakes: fewer geographical locations for plants*

Back in 2008, ADWEC was already pointing to the difficulties in finding locations for additional desalination water capacity. It stated cautiously: 'Some further potential for expanding capacity may exist at or close to the existing Fujairah, Umm Al Nar and Al Mirfa sites.'

Between 2008 and 2013, water and power capacity was indeed increased in Fujairah (from 102 MIG to 233 MIG for water capacity and from 641 MW to 2,975 MW for electricity).[88] The Mirfa site is also being expanded, thanks to the creation of a new power plant of 1,600 MW of electricity replacing the existing 186 MW plant, with a seawater RO desalination capacity of 52.5 million gallons per day.[89] For the Umm Al Nar site, which is the closest to Abu Dhabi Main Island, ADWEC has been expressing concerns about the environmental impact of a CCGT plant. 'Further adding combined cycle plant at Umm Al Nar with/without desalination capacity would result in large amounts of heat being rejected into the surrounding seawater. Since this additional heat would cause environmental problems a combined cycle expansion is considered imprudent. Consequently the Umm Al Nar site will probably have open cycle peaking capacity installed in the future.'[90] Globally, ADWEC estimated that 'finding new coastal site locations (…) may prove challenging.'

For groundwater, EAD has already warned about the increasing salinity, which requires either desalination or refilling with desalinated water. However, the current desalination production based on gas fuel or natural gas 'contributes to climate change and brine discharges contribute to the deterioration of marine life.'

88. ADWEC, 'Statement of Future Capacity Requirements 2008 – 2030' (Abu Dhabi, 2008), p31.

89. LeAnne Graves, 'Mirfa power and water plant to begin construction in February' (*The National*, December 27, 2014).

90. ADWEC, *Ibid*, p.32.

- *Social issues: the rent dilemma*

The long-term perspective of the energy sector does not protect it from short-term volatility risks. In particular, when budget revenues largely depend on oil income, as is the case of the Government of Abu Dhabi, short-term downturns can have big impacts on long-term policies. Furthermore, because of the water and electricity market structure, subsidies and fuel risks are borne by the Government. The Government is thus responsible for the optimization of fuel procurement for IWPP, since it is ADWEC (a 100% subsidiary of state-owned ADWEA), which purchases the gas and the back-up gas fuel mainly from state-owned ADNOC. Falling prices are therefore benefitting ADWEC, but lower prices also mean less income for ADNOC and the Government. With the current intertwined system (the oil rent goes to the Government that redistributes it to the citizens in form of subsidies and cheap fuel), there is no possible win-win solution, only difficult trade-offs. As domestic resources are diminishing or their production cost is increasing,[91] hedging against volatility means diversifying suppliers and energy sources for desalination. Also, reducing the reliance on natural gas and fuel oil could lower the tension among competing domestic sectors and could provide for a better use of these fuels. Additional solutions are therefore needed to cope with future increasing demand.

- *A new strategy for the water system*

There is another important limit complementing the three systemic difficulties of the present water management, namely imminent capacity shortfalls. ADWEC Winter 2012/2013 forecasts show that the system should be already short of 18 million imperial gallons per day (MIGD) by the end of 2015. With added desalination capacity of 53 MIGD at Mirfa, the system should re-balance until 2016-2017. However, no additional capacity is planned, raising risks of shortages.

The *Abu Dhabi Environment Vision 2030* targets aim at reducing ground- and desalinated water consumption by increasing the effective use of recycled water and by better management of leakage in the network (see Annex 3). A target of 100% of recycled water consumed would constitute an incredible reduction in the pressure on groundwater resources, and reduce the current consumption of desalinated water by the agricultural sector to zero. If recycled water were used for agriculture irrigation or in mega-project garden irrigation, it could substitute desalinated water consumption (on the condition of re-using network availability which is not currently the case) for roughly 317 mcm of water per year, or 191 MIGD. In

91. The quality of the new fields seems inferior to that of the historical ones. The Shah and Bab sour gas fields' development is on track but additional treatments are needed to eliminate toxic sulphur, which will raise production costs. MEES, 'UAE says oil price will not impact expansion'(Vol.57 No.46, 14 November 2014) 12.

addition, the claimed physical losses of the distribution system were 20,781 MIG. Finally, if demand-side policies can effectively influence long-term consumption patterns, then overall demand could flatten and eventually stabilize.

If these trends are confirmed, then the power to water ratio will increase, meaning new electricity capacity will be needed more substantially than water. ADWEC has already predicted that power demand will increase faster than water as new mega projects will require substantial electricity input. ADWEC suggests that more RO technology could be added as it uses 100% electricity input to produce water and does not produce any electricity. Nuclear and renewable energies will increase electricity capacity, without requiring massive gas inputs.[92] As a consequence, a progressive de-coupling of the water and electricity system could take place which will help securing both energy and water supplies.

However, TRANSCO[93] fears that the overall flexibility and efficiency of the system will be penalized. Nuclear power is mainly used for base-load generation, and solar power is available only during day light. Demand, on the other hand, peaks daily at around 5 pm. Other flexible sources will therefore be needed. Also, current cogeneration power plants will still be connected to the system, ensuring a steady flow of water and power. Negotiations are therefore under way among regulators and operators, in order to limit the use of nuclear plants to 60% of their capacity only.

92. Gas as a back-up fuel will still be needed for photovoltaic electricity production. ADWEC states 'the Emirate of Abu Dhabi's daily peak electricity demand typically occurs around 4:50 pm each day, when split shift offices / shop etc. reopen and the heating effect on buildings (delayed by around 2 hours because of insulation from walls) combines with high humidity levels to produce peak demand. It is planned that a supporting back-up fuel (natural gas) will be used by MASDAR to increase the solar plants' output during the afternoon hours, when electricity demand is at its highest.'

93. Discussion with a representative of TRANSCO under condition of anonymity.

Conclusion

The current management system of water resources in the GCC states has reached its limits. Overconsumption of groundwater and desalination has led to unexpected consequences. Increasing desalinated water production backed by cheap domestic fuels has forced some oil and gas rich countries to import fossil fuels or to ban exports. Water consumption, however, is mainly driven by subsidized agricultural policies and domestic tariffs. Given the social sensitiveness of the sector, innovative policies and alternatives are being sought, before tackling demand-side policies. Desalinated water has been coping with increasing demand, but as a result, GCC countries now face more urgent questions related to the security of supply of their energy intensive water systems. Ambitious but necessary reforms are therefore underway.

In particular, a more diversified mix of water production technologies gives greater flexibility in electricity generation. While cogeneration thermal desalination technologies have proven their efficiency, a strong reliance on this energy-power mix is not a long-term solution. Nuclear power and renewables are therefore entering the energy/water scene as they could replace some targeted uses. Small RO plants run by solar photovoltaic power in agriculture or solar well pumps diminish the need of fossil fuel electricity. Nuclear energy will be able to power large-scale RO plants, as it will be the case in Abu Dhabi and maybe Saudi Arabia. Stand-alone gas-fired power plants will still be needed as they can replace heavy fuel power plants, in order to provide flexibility while emitting lower CO_2 emissions. While solar and nuclear power are clean and reliable, their base-load operations cause some problems in peak and unexpected situations, as the Abu Dhabi case study clearly shows.

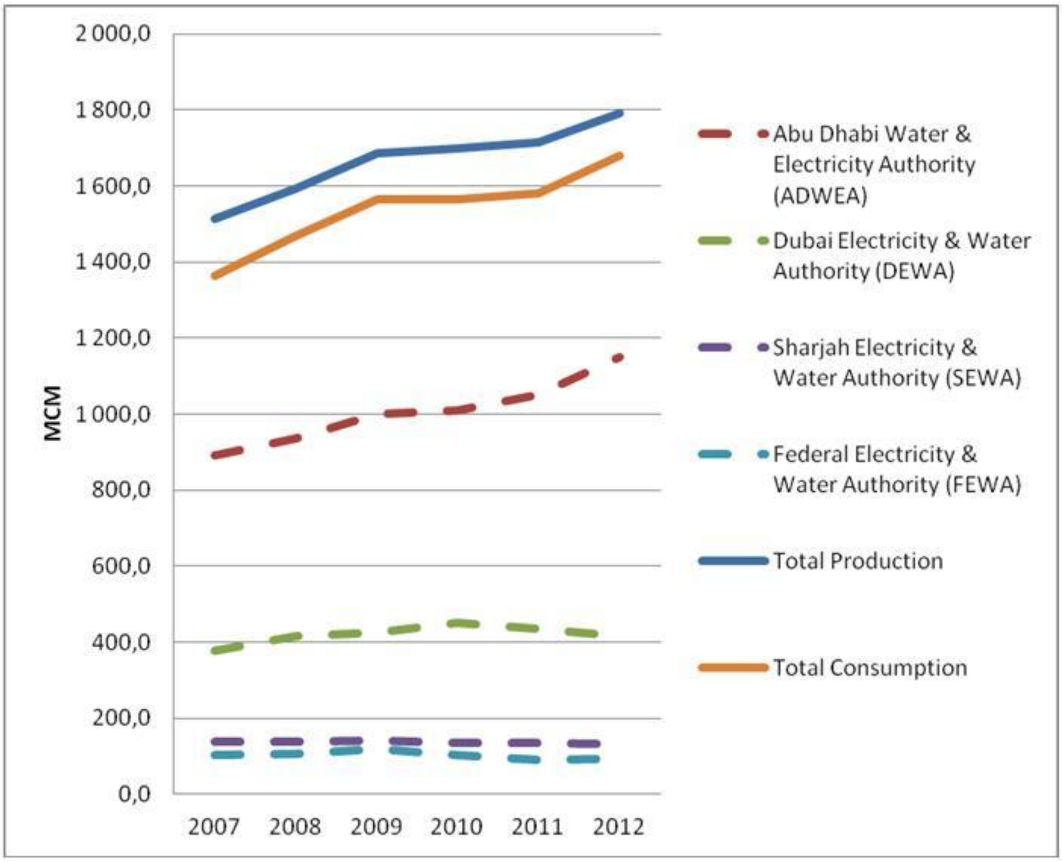
Also, as increasing desalination capacity requirements have demanded the development of large-scale infrastructures, environmental concerns have arisen. High salinity levels are jeopardizing agricultural activities and endangering the few fresh water resources left in the aquifers. The case of Abu Dhabi shows that increasing salinity is deteriorating aquifers too, and if no action is taken groundwater will be too saline to be used in agriculture. Also, salinity in Gulf waters might limit the location choice of new plants. Abu Dhabi is currently looking for solutions on the Gulf of Oman, where salinity levels are lower.

The Strategy proposed by the Abu Dhabi Government for the year 2014-2018 goes in the right direction, as it sets clear (though not mandatory) targets that will help to improve water re-use, shift resources without adding new desalination capacity and, overall, optimize the system. This could be a source of inspiration for future water strategies, such as in the Qatar National Water Act.

Finally, intra-regional co-operation in the form of a unified strategy, a common Water Law and a common water tariff structure remains key to saving scarce resources and reducing the risks of social unrest.

Annex 1

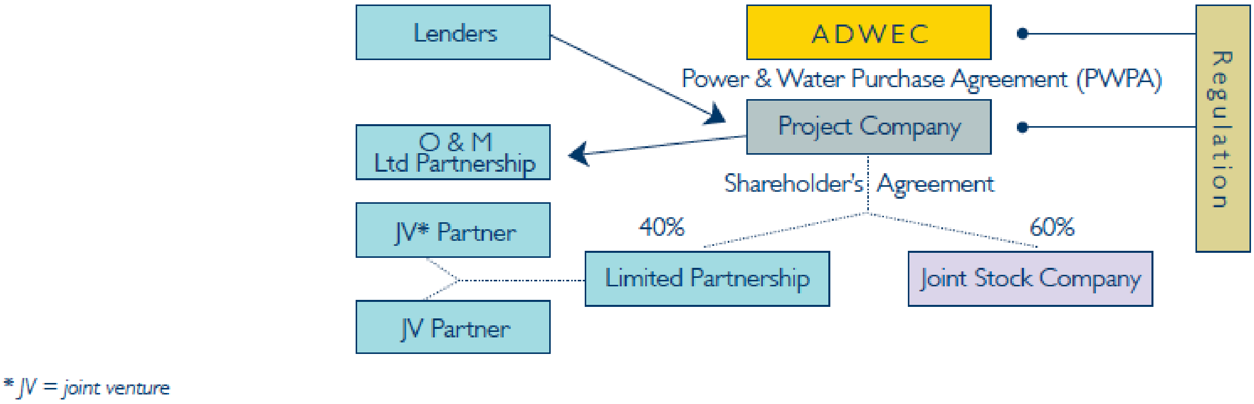
Water Production United Arab Emirates, 2007 – 2012 mcm per day



Source: United Arab Emirates National Bureau of Statistics, Water 2012.

Annex 2

Typical IWP structure



Source: Source: RSB Sector Overview 2010-2013.

Annex 3

Abu Dhabi Environment Vision 2030, EAD

ABU DHABI ENVIRONMENT VISION 2030 ENVIRONMENTAL PRIORITIES, OUTCOMES AND TARGETS						
PRIORITY AREA	**PRIORITY**	**OUTCOME**	**MEASURE**	**BASELINE 2010**	**TARGET 2018**	**TARGET 2030**
Efficient management and conservation of water resources	Integrated and Efficient Use of Water Resources	Moderated average domestic indoor and outdoor water consumption	Domestic Water Consumption in L/capita/day	614	450	<340
		Maximised use of recycled water	% of Total Recycled Water Consumed	51%	100%	100%
	Sustainable Management of Groundwater Resources	Sustainable Groundwater Reserves	Effective Years Remaining in Usable Groundwater Reserves	<55	65	>74
		Increases in salinity in groundwater reserves within acceptable limits	Average salinity of abstracted groundwater	NA	TBD	TBD

ABU DHABI ENVIRONMENT VISION 2030 SECTOR-SPECIFIC PRIORITIES, OUTCOMES AND TARGETS					
SECTOR	**IMPERATIVE**	**MEASURE**	**BASELINE 2010**	**TARGET 2018**	**TARGET 2030**
Energy and utilities	Ensure proper demand side management for efficient water consumption patterns	% of 2010 water tariff rate	100%	TBD	Cost-reflective water tariffs
	Minimise water losses from desalinated water networks	% of transmission and distribution losses (out of produced desalinated water)	20%	15-17%	10%
	Minimise discharges from recycled water practices	% discharge from recycled water practices (flow discharge measurement taken for peak season)	49%	10%	10%
	Adopt innovative clean solutions for water production in light of energy plans	% of new desalinated water capacity using clean technologies (low carbon and renewables)	0%	0%	100%
	Limit the impact of desalination water practices on marine and terrestrial ecosystems	Degradation index (Marine and terrestrial degradation attributed to desalination water is minimised) (1.00=zero degradation)	TBD	TBD	1.00
Buildings and Infrastructure	Ensure high indoor water efficiency in built environment	% of reduction in water use intensity of existing and new buildings relative to 2010	0%	10%	25%
	Ensure high outdoor use water efficiency in buildings, villas and shabiyyat	% of reduction in outdoor water use intensity of buildings, villas and shabiyyat relative to 2010	0%	12%	30%
Agriculture and Livestock	Optimise water use including groundwater, desalinated and recycled water for Agriculture while ensuring food security	Annual groundwater abstraction in Million m^3 and % water efficiency improvement[12]	1,714 Mm^3	1,400 Mm^3	<755 Mm^3 TBD
	Minimise groundwater pollution and salinization attributed to agriculture	% measured application of fertilisers and pesticides	TBD	TBD	100%
Public Realm, Amenities and Forestry	Develop low water requirement public realm amenities and forestry sectors	% of reduction in the average water use intensity of all public realm amenities relative to 2010	0%	16%	60%

Source: EAD.

Tables and Figures

Acknowledgements

The author would like to thank the Paris Sorbonne University Abu Dhabi for the reviews and for the participation in the 'Comparative Law and Sustainable Development' research program led by Anthony Chamboredon, as the scientific coordinator, at the 'Department of Law, Political Sciences, Economics and Management Research Initiative'.

The author also thanks Marie-Claire Aoun, Director of Ifri's Center for Energy, for having enthusiastically supported the idea of this paper and for her useful comments and suggestions. Last, but not least, thanks to Maïté de Boncourt, Ifri Associate Research Fellow and specialist of the Middle East region, for having shared her knowledge.

References

ADWEC, ‘Statement of Future Capacity Requirements 2008 – 2030’, (Abu Dhabi 2008)

ADWEC, ‘Bulk Supply Tariff’ (2011)

ADWEC, ‘Statistical Leaflet 2003’, (ADWEC, 2004)

ADWEC, ‘Statistical Leaflet 2004’, (ADWEC, 2005)

ADWEC, ‘Statistical Leaflet 2005’, (ADWEC, 2006)

Banque Mondiale, ‘Hauteur moyenne des précipitations (mm par an)’, <http://donnees.banquemondiale.org/indicateur/AG.LND.PRCP.MM accessed 05/01/2015>

BP Statistical Review 2014

Demouliere R., Bensaid Schemba J., Berger J., Aït Kaci A., Rougier F., ‘Public water supply and sanitation services in France Economic, social and environmental data’, *Les entreprises de l’eau*, (BIPE 2012)

EAD, ‘Annual Report 2013’ (Abu Dhabi, 2014)

EAD, ‘Abu Dhabi Environment Vision 2030’ (Abu Dhabi, 2009)

EAD, ‘Advancing sustainable groundwater management in Abu Dhabi’, December 2012

EAD, ‘Maximizing recycled water use in the Emirate of Abu Dhabi’ (Annual Policy Brief, 2013)

EAD, ‘Water resources management strategy for the emirate of Abu Dhabi, A High Level Strategy and Action Plan for the Efficient Management and Conservation of Water Resources’ (Government of Abu Dhabi, 2013)

ETSAP, IRENA, ‘Water Desalination Using Renewable Energy’, *Technology Brief* (2012)

Maïté de Boncourt, ‘Energy Strategy of the GCC countries’ (Paris: 2012)

M.A. Darwish & Rabi Mohtar, Qatar water challenges, ‘Desalination and Water Treatment’, DOI:10.1080/19443994.2012.693582 (2012)

Droogers P., Immerzeel W. , Terink W. , Hoogeveen J. , Bierkens M. F. P. , van Beek L. P. H. , and Debele D., ‘Water resources trends in Middle East and North Africa towards 2050’, *in Hydrology and Earth System Science*, 16, 3101–3114 (2012)

Everington J., ‘Adia reaffirms commitment to emerging markets’, www.thenational.ae, July 1st 2014

FAO, ‘Groundwater Management in Saudi Arabia, Draft Synthesis Report’ (Rome, 2009)

Fischer S., ‘Fuel Cost Allocation in Cogeneration Production of Power and Water’ (MEED 3rd Middle East Power and Water, Abu Dhabi, March 2006)

Gwenn Okruhlik in ‘Rentier Wealth, Unruly Law, and the Rise of Opposition: The Political Economy of Oil States’, in *Comparative Politics*, April 1999

King Abdullah University of Sciences and Technology, ‘The KICP Annual Strategic Study, Promoting Wastewater Reclamation and Reuse in the Kingdom of Saudi Arabia:

Technology Trends, Innovation Needs, and Business Opportunities’, Krane J, ‘An expensive diversion: Abu Dhabi’s renewable energy investments amid a context of challenging demand’ (James a. Baker III Institute for Public Policy of Rice University, 2014)

IRENA, ‘Renewable energy in the water, energy & food nexus’ (Abu Dhabi, 2015)

Miller K., ‘The Prospects for Electricity Trade Between the GCC Countries’ (MEED 2nd Middle East Power and Water, Abu Dhabi, March 2005)

Miller K., ‘ADWEC Winter 2012 / 2013 Electricity and Water Demand Forecasts’ (ADWEC, 2012)

Miller K., ‘ADWEC (Winter 2008 / 2009) Electricity & Water Demand Forecast 2009 – 2030’ (ADWEC, 2008)

Ayoub J., El Sayed T., ‘Achieving a sustainable water sector in the GCC’ (Strategy&, 2014)

‘GCC to set up common water grid’ (Emirates 24-7, published Monday, September 30, 2013) www.emirates247.com

Graves L., ‘Mirfa power and water plant to begin construction in February’ (The National, December 27, 2014)

MEES, ‘UAE says oil price will not impact expansion’(Vol.57 No.46, 14 November 2014)

Miller K., ‘ADWEC Winter 2012/2013 Electricity and Water Demand Forecasts’ (ADWEC, 2012)

RSB, ‘Supporting the Abu Dhabi Economic Vision 2030’ (Regulation & Supervision Bureau, 2014)

RSB, ‘Water and electricity sector overview 2010-2013’ (Regulation & Supervision Bureau, 2014)

RSB, 'Technical Sector Report 2012' (Regulation & Supervision Bureau, 2014)

RSB, 'Sector overview 2010-2013' (RSB, 2013)

RSB, 'Annual Economic Report 2013', (RSB, 2014)

RSB, 'Statement on electricity and water costs 2013 – 2014', (RSB, 2014)

SACD, 'Statistical Yearbook 2009, 2010, 2011, 2012, 2013' (www.scad.ae)

Sommariva C.,'Desalination and advanced water treatment' (Baban Desalination Publications, 2010)

TRANSCO, 'Seven Year Water Planning Statement (2014-2020)' (Transco, 2013)

TRANSCO, 'Seven Year Electricity Planning Statement (2014-2020)' (Transco, 2013)

UAE Interact, 'Oil and gas', accessed

Woertz E., 'Arab Food, Water and the Big Gulf Landgrab that Wasn't' in *The Brown Journal of World Affairs*

Main websites

Abu Dhabi investment Authority www.adia.ae

Regulation and Supervision Bureau (Abu Dhabi, UAE) www.rsb.gov.ae

Electricity and Water Authority of Bahrain www.mew.gov.bh

Power and water authority Oman www.paew.gov.om

Oman Power and Water Procurement Corporation www.omanpwp.com

National Water Company www.nwc.com.sa

Saline Water Conversion Corporation www.swcc.gov.sa

Ministry of Electricity and Water Kuwait www.mew.gov.kw

Qatar Water and Electricity Corporation www.qewc.com

Qatar General Electricity and Water Corporation (Kahramaa) km.com.qa

Global Water Intelligence, www.globalwaterintel.com

Arab Forum for Environment and Development, www.afedonline.org