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Qatar water problem and solar desalination

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ABSTRACT

The reasons of water problem in Qatar are outlined. The water resources include very limited ground water that is heavily exploited, desalted seawater consuming too much energy and negatively affecting the environment, and treated wastewater that is not fully utilized. Heavy water leakage in the distribution network is an added problem. Water consumption is high due to the government heavy subsidization. The population increase and the rising standard of living are increasing the water demand, and there is clear demand gap that eventually should secured by desalination. Using solar energy can be a sustainable solution that is considered in the paper. Although it is expensive, the prospect of decreasing the cost exist.

Keywords: Qatar water problem; Water resources; Groundwater; Wastewater; Treated wastewater; Desalination; Multi stage Flash; Thermal vapor compression; Seawater reverse osmosis; Water demand; Water consumption; Water leakage; Solar desalination

1. Introduction

The Qatar water problem is resulted from: very limited natural water resources, very limited-replenished ground water that is overexploited, depleted, and quality deteriorated; full dependence (99%) on desalted seawater (DW) to satisfy potable water and household needs, using desalting systems that consume extensive fuel amounts, emitting greenhouse gases (GHG) at high rates; and negatively affecting the environment; high desalted water production cost, vulnerable desalting water system, high leakage from water supply network and untreated sewage water to water table, lack of strategic water storage capacity, high water consumption per capita, unrealistically low, (or no) water cost to consumers and lack of incentives to conserve water, lack of awareness of water value in homes and public buildings, and lack of institutions to carry integrated water managements.

The Desalination Group in Qatar Environment and Energy Research Institute (QEERI) reviewed the main issues related to this water problem in order to identify topics that can be studied by the group and to collaborate with other concerned stakeholders in building an economically viable and ecologically resilient water resource management.

2. Water resources in Qatar and other Gulf Co-operation Countries (GCC)

Qatar relies on water from three sources: desalination, groundwater (GW), and recycled municipal treated wastewater (TWW) water, all subject to inefficiencies

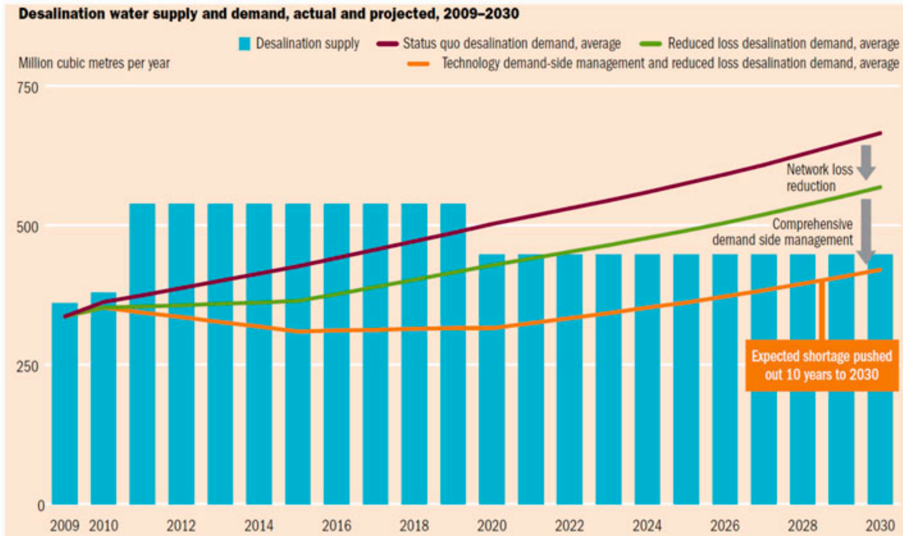

Fig. 1. Qatar desalination present and projected capacities [1].
Source: National Development Strategy 2011–2016 estimates.

that may create stresses and eventually pose a threat to water security or require large investments to ease shortages [1].

2.1. Desalination

DW accounts for about half the water used in the country. Fig. 1 shows the present and projected desalting seawater capacity in Qatar as given by Qatar National Strategy 2012–2016 [1]. Rapid population growth, raising standard of living, and urbanization resulted in rising demand of DW. The consumed DW increased from 173 million cubic meters (Mm^3/y) in 2004 to 373 Mm^3/y in 2010, more than doubled in 6 years. Desalination in Qatar is subject to inefficiencies that may threaten water security or require large investments to ease shortages [1].

Two main thermal desalting seawater methods are used in Qatar, namely multistage flash (MSF), Fig. 2, and thermal vapor compression-multi effect (TVC/ME) systems are shown in Fig. 3 [2]. Application of the more energy efficient seawater reverse osmosis (SWRO) process is shown in Fig. 4 [3], started one year ago to be used in the Pearle project by a private company for municipal water supply. The use of SWRO is thought to be expanded by the National Qatar Electricity and Water Corporation, mainly due improvement in SWRO feed pretreatments, low consumed energy, increased reliability, and low production cost.

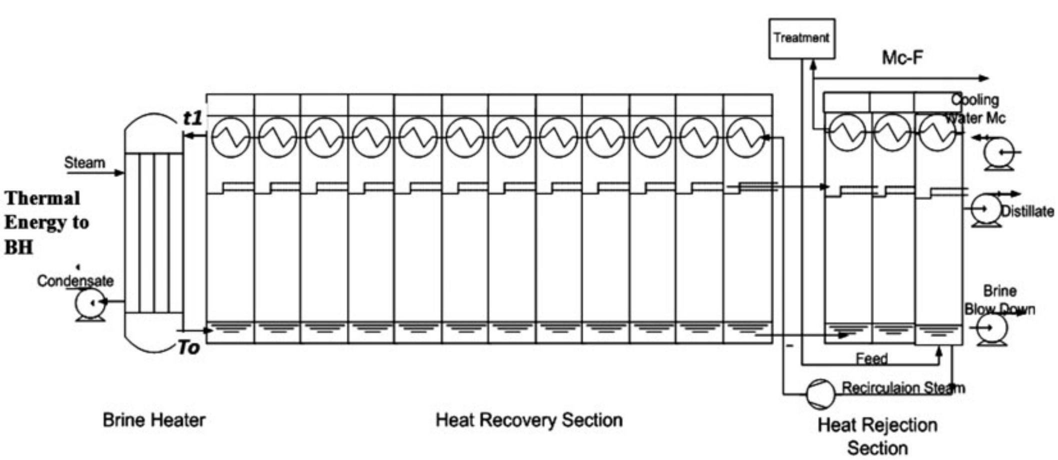

Fig. 2. Schematic diagram of an MSF unit consisting of n stages.

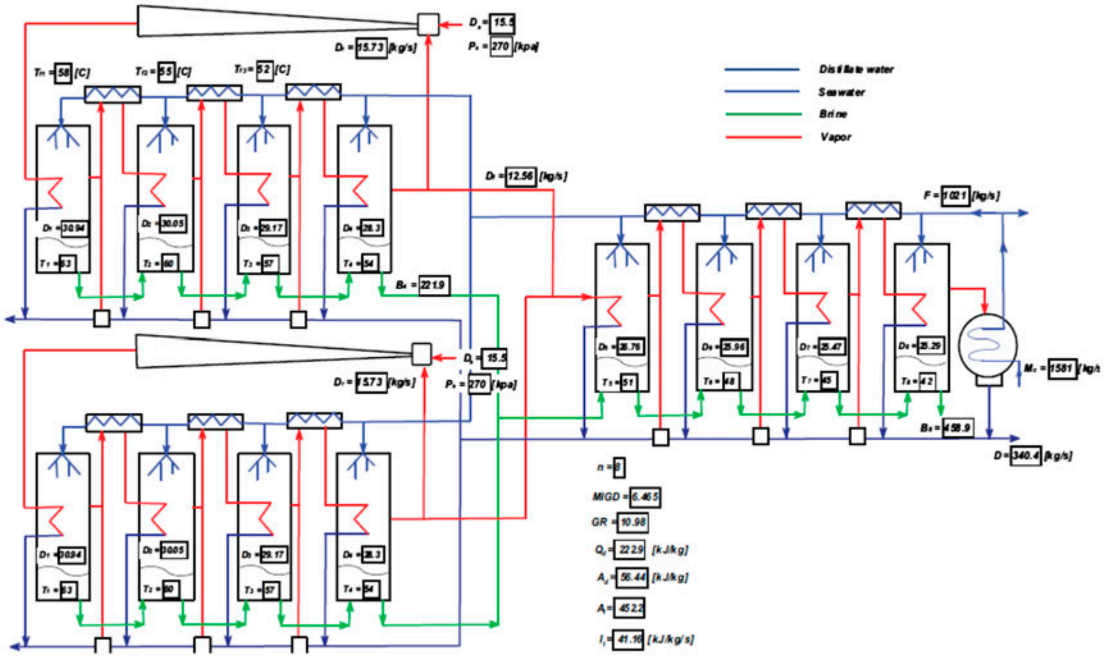

Fig. 3. Schematic diagram of ME-TVC-ME unit, 6.5 MIGD [2].

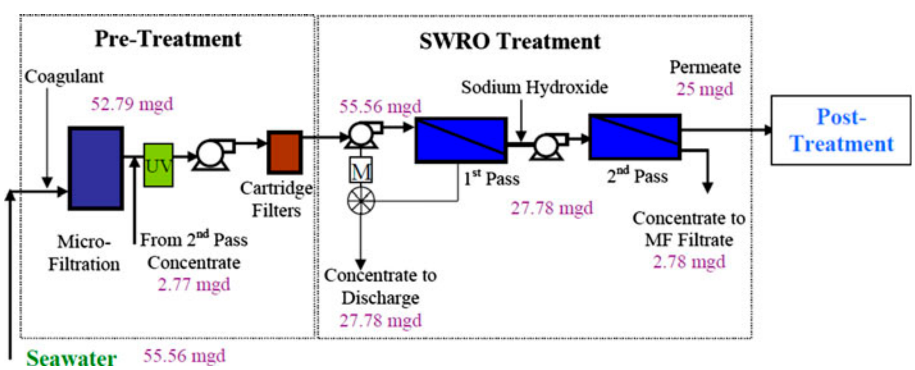

Fig. 4. SWRO schematic flow diagram [3].

The consumed thermal energy for the MSF or TVC/ME systems is about 260 MJ/m^3 of DW, and the pumping energy is 4 kWh/m^3 for the MSF system and 2 kWh/m^3 for the TVC/ME system. The total consumed equivalent mechanical energy is 20 kWh/m^3 for the MSF system 18 kWh/m^3 for the TVC/ME system, and 5 kWh/m^3 for SWRO systems. If the estimated cost of 1 kWh equivalent work is \$0.11 [4], then the energy cost to produce 1 m^3 of desalted water is \$2.2 for the MSF, \$1.98 for TVC/ME, and \$0.55 for SWRO systems. This is the energy cost only, while the typical DW is \$2.75/m^3 for MSF, \$2.48/m^3 for TVC/ME, and \$1.1/m^3 for SWRO systems without the distribution cost; by assuming the cost of energy represents 50% for SWRO and 80% for both MSF and TVC/ME systems.

The situation in the other GCC is similar to that in Qatar. The GCC, Saudi Arabia (SA), United Arab Emirates (UAE), Oman, Kuwait, Qatar, and Bahrain are relying increasingly on DW to satisfy their municipal and industrial water needs, and this is expected to continue the future, Figs. 5 and 6. As in Qatar, the mainly used desalting in the GCC systems are MSF and TVC/ME; and SWRO method is penetrating the GCC market at high rates.

Desalination is expensive and energy-intensive. Most of the GCC are struggling to secure the Natural gas (NG) needed to run their cogeneration power desalting plants (CPDP). As example, Kuwait, UAE started to import NG. SA, the largest oil exporter in the world is burning about 1.5 million barrels of crude oil equivalent daily to produce both electric power

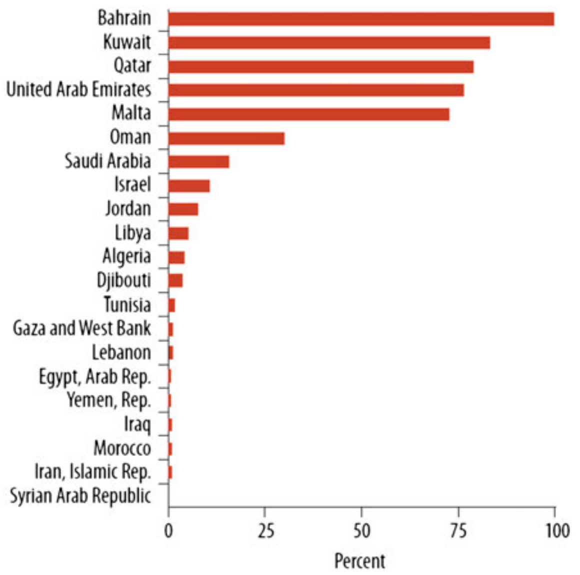

Fig. 5. Share of National Water Demand in MENA Met by Desalination, 2010 [4].

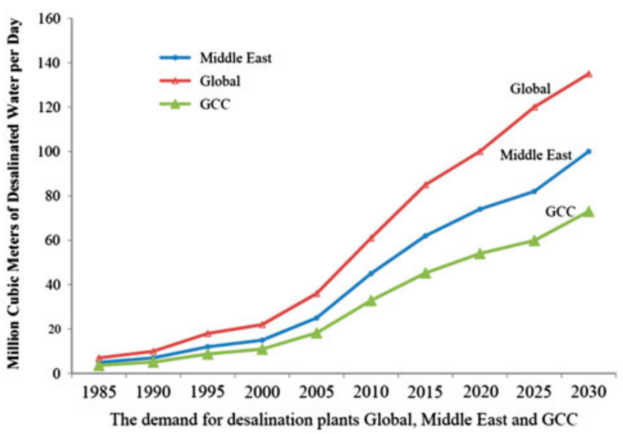

Fig. 6. Current and expected demands for DW in the GCC, Arab countries, and world [5].

(EP) and DW, and this is not sustainable. Reducing the cost of DW, reducing its reliance on fossil fuel, and mitigating its environmental impacts are crucial.

Losses of DW in Qatar due to leakage distribution piping are high (30%–35%) as shown in Fig. 7 [1]. If one third of the produced DW estimated by 420 Mm^3/y DW in 2012 is 140 Mm^3/y, the DW loss cost is \$385 M (more than Billion QR).

In 2008, the annual produced DW was 312 Mm^3, Fig. 7. It was partially supplied as municipal water (200 Mm^3), while 100 Mm^3 was leaked to the ground and raising the water table. Out of the municipal water, 75 Mm^3/y was rejected as untreated sewage from unconnected homes to sewage system (to the water table also); and out of 96 Mm^3 collected sewage, 20 Mm^3 was also leaked to the water table. So, the water table received 100 Mm^3 produced water, 95 Mm^3 of untreated sewage (or 62.5% of total water).

The unaccounted for water (UFW) which exceeds 30% in Qatar and SA should be reduced to about 15–20%. Water meters should be installed and maintained on regular basis in order to provide accurate and reliable water use measurement. More frequent leakage inspections and advanced pressure control system for water distribution networks should reduce leakages.

2.2. Groundwater

The annual renewable water resource in Qatar is estimated as 58 Mm^3/y and the average share in 2010 is 33 m cube per capita (m^3/capita) [6]. Qatar natural water total withdrawal in 2009 was 400 Mm^3/y (almost 6.9 times the replenishment rate), including 236 Mm^3/y for agriculture, 8 Mm^3/y for Industry, and 156 Mm^3/y for domestic uses. So, GW is severely over-exploited. The situation in the GCC is similarly named as shown in Tables 1–3 [6].

Meanwhile, quality of the GW system is a growing concern. Brine produced by certain farm processes is discharged back into the ground, raising the salinity of the remaining GW.

Since this water is later deployed for irrigation and other agricultural uses, it increases the salinity of the soil. Substantial parts of GW reserves show salinity levels above what is considered suitable for irrigation.

The Fossil GW is a finite and irreplaceable once being mined. Many farms in Qatar stopped farming. Using alternative resource such as desalination is very expensive. Mining GW may benefit the country in the short term; but it is real loss in the in the longer term as this water is considered as the country national wealth. Agriculture consumes around 60 to 90% of water, while accounts for only 2–7% of GDP in SA, UAE, and Oman. The agriculture sector is much more insignificant in Bahrain and Qatar with less than 1% of GDP while still using around 50 to 60% of water.

Since agriculture makes heavy demands on GW water, with minimal contribution to country GDP, it is required to reduce the consumed water in agriculture. Irrigation methods used in Qatar that involve flooding fields with high losses from evaporation should be replaced by more water efficient water usage such as drip irrigation system, which uses much less water for a given yield.

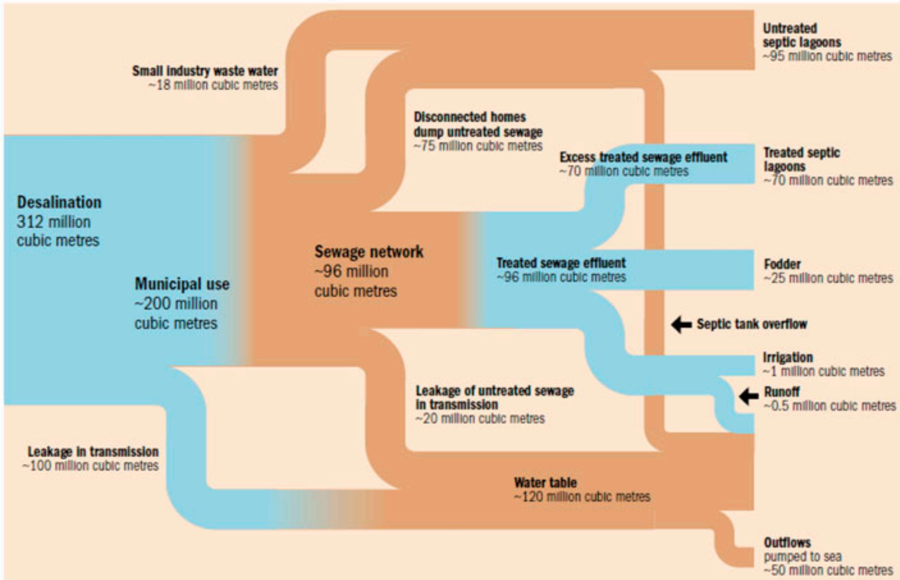

Fig. 7. Qatar water leak into the water table each year [1].

Table 1
Renewable water resources and per capita share in the GCC [6]

Country/sub-region	Natural water resources (million m^3)	Average share (m^3/capita)		
		2010	2030	2050
Bahrain	116	92	70	64
Kuwait	20	7	5	4
Oman	1,400	503	389	374
Qatar	58	33	24	22
Saudi Arabia	2,400	87	62	53
United Arab Emirates	150	20	14	12
GCC	4,144	95	68	59
Yemen	2,100	87	51	34
GCC and Yemen	6,244	92	61	47

Table 2
Water withdrawal and uses of natural water (2009) in the GCC [6]

Country/sub-region	Natural water resources (million m^3)	Average share (m^3/capita)		
		2010	2030	2050
Bahrain	116	92	70	64
Kuwait	20	7	5	4
Oman	1,400	503	389	374
Qatar	58	33	24	22
Saudi Arabia	2,400	87	62	53
United Arab Emirates	150	20	14	12
GCC	4,144	95	68	59
Yemen	2,100	87	51	34
GCC and Yemen	6,244	92	61	47

The situation is similar in the GCC, the available annual freshwater resources per capita ranges make the GCC region the least natural water resources in the world. Fig. 8 shows that water withdrawal (from GW and desalination) is much more than the fresh water renewable resources, and that taken from GW is even more than DW, and this is not sustainable. All GCC, including Qatar, should have strategy for sustainable water supply.

2.3. Recycled treated waste water (TWW)

Recycled water, or TWW effluent is a guaranteed water resource, increases with population growth, and can represent high percentage of domestic water use. Qatar lacks the infrastructure to deliver recycled water to every potential user. Investments are needed to extend collection and treatment networks; and public campaign for its recycled water acceptance is needed. Recycled TWW effluent, accounts for 14.9% of the water use. The TWW supply currently is more than demand, and about 40% of treated sewage effluent is discharged into septic lagoons. Some WW, particularly from industrial users, is not treated and is discharged or stored in tanks that could leak, and contaminates the limited supplies of GW. Qatar could make far more extensive use of recycled water, which cost about one quarter of the DW [1]. Water demand for

Table 3
Water withdrawal in the GCC as percent of annual fresh water resources (2009), [6]

Country/sub-region	Natural water resources (million m^3)	Average share (m^3/capita)		
		2010	2030	2050
Bahrain	116	92	70	64
Kuwait	20	7	5	4
Oman	1,400	503	389	374
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Saudi Arabia	2,400	87	62	53
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irrigation in the GCC can be satisfied by properly treated waste water, as the GW is limited and already exploited and depleted.

In 2005, about 80% of total reused TWW was distributed to El-Rakeya and El-Refaa farms for growing fodder and to Doha for landscape irrigation; the remainder was discharged into an emergency lake at Abu Nakhla area. TWW using tertiary-level treatment of municipal wastewater was found to be adequate for irrigating ornamental plants and growing fodder. The recycled TWW may also be suitable for irrigating trees. However, more advanced treatment technology would be required for irrigating vegetables and other crops for human consumption, or for recharging GW aquifers.

The reuse of TWW was limited to irrigating tree (1 Mm^3) and fodder crops (25 Mm^3).

Rising water table is a challenge for Doha. About a third of Qatar's desalinated water, some sewage water, and overflowing water from some septic tanks are leaking to water table. These pose serious health hazards and costs for building project. The main response to the problem has been regular pumping of excess water into the sea, but that practice may be harming the marine environment.

Qatar is behind UAE and Kuwait in utilizing TWW as another water source, see Table 4. In Qatar, only 14.9% of the produced wastewater (about 90% of domestic water supply) is treated, and only 65% of it

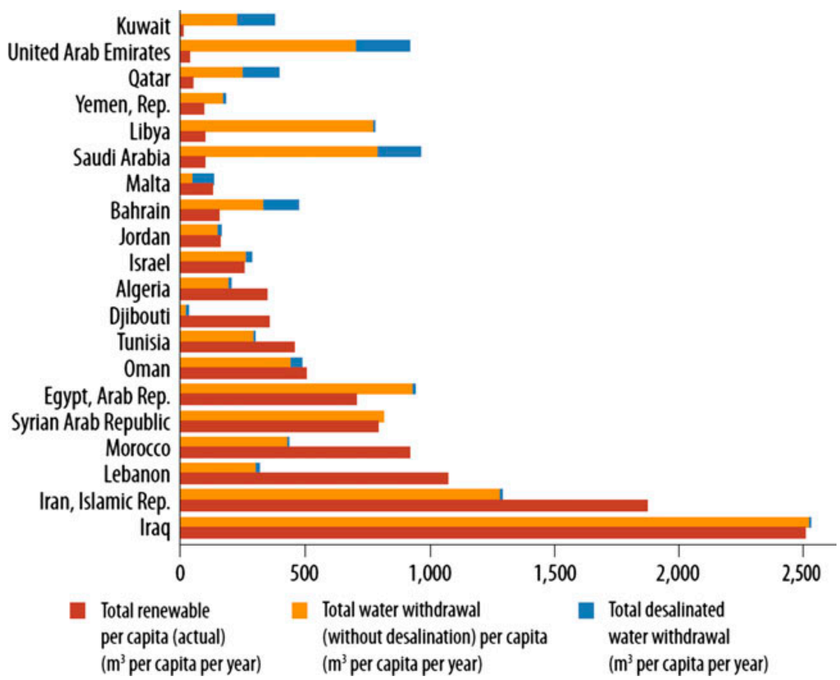

Fig. 8. Renewable fresh water, water withdrawal, and DW in the Arab countries including the GCC, [4].
Source: Modified from FAO AQUASTAT 2009. Note: AQUASTAT is FAO's global information system on water and agriculture, developed by the Land and Water Division. No relevant FAO data were available for West Bank and Gaza Strip. The Saudi Arabia data were modified based on the GWI desalination database since the FAO data included only desalination figures from the Saline Water Conversion Corporation (SWCC), not the total desalination production capacity in the Kingdom. Total renewable water is based on data between 1960 and 2010; data for Djibouti are unreliable. http://www.globalwaterintel.com/client_media/uploaded/GWM_2011_sample_chapter.pdf.

Table 4
Water withdrawal, wastewater produced, treated waste water, and Reused TWW, [7]

Country/sub-region	Natural water resources (million m^3)	Average share (m^3/capita)		
		2010	2030	2050
Bahrain	116	92	70	64
Kuwait	20	7	5	4
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is reused; while in UAE (and Kuwait), 91% (95.6%) of the produced wastewater is treated, and 55% (and 33%) of it is reused.

In Abu Dhabi, urban areas generate roughly 550,000 m^3 of wastewater daily and are treated in 20 wastewater treatment plants. All facilities are equipped to treat effluent for reuse in irrigation.

It is clear that treating wastewater to different level is at a cost, see Fig. 9, but it is still far less than desalting seawater.

The Desalination group in QEERI has a joint project with Ghent University in Belgium to further treat the tertiary effluent from waste water treatment plants in Doha to potable conditions. Ultra filtration followed by and reverse osmosis (RO) are to be tested to determine the qualities of water produced from this treatment. The quality of the MF/RO unit effluent should be suitable for aquifer injection, as set by the Ministry of Environment standards for infiltration into drinking water aquifers.

Similar experiments were conducted, and showed that the concentrate from both the RO is well within the range of Food and Agriculture Organization irrigation water guidelines for crops [8]. However, this has to checked, especially with boron level in the RO concentrate which may be high for sensitive crops. One of the project aims is to obtain data for the design of a full-scale plant.

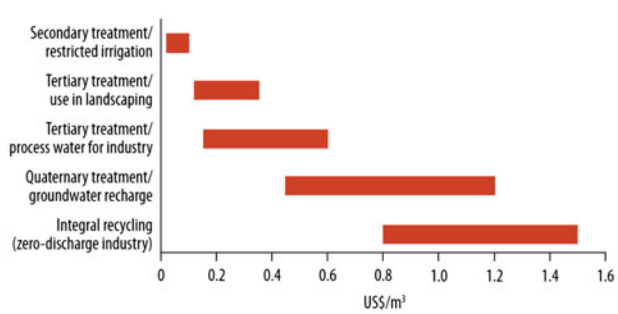

Fig. 9. Cost range for water reuse [4].

3. Growing water demands

The economic development in Qatar and other GCC due to the discovery and export of oil and natural gas is directed towards improving the population standard of living. Water supply and sanitation services have been made accessible, e.g. 100% in Qatar, as example. In the GCC, population life expectancy increased by about 10 years during the period 1980–2000 [9]; reached 78 years in Qatar in 2011, literacy rates rose from 20% to about 80% over the same period. Rapid increase in Urban Water Demand is due to rapid population growth and the rise of the capita consumption. As an example, in March 2013, the reported population of Qatar was 1.92 M from 1.67 M in April 2010, 1.31 M in 2009, 0.522 M in 1997, and 0.37 M in 1986. It is well known fact per capita domestic water consumption is directly proportion to the GDP per capita, see Fig. 10. In Qatar, as example, the GDP income reached $173 Billion and GDP per capita income $80,440 in 2011 [10]. The services needed by the water sectors are expanded significantly as well as the water demand.

Water tariffs in the GCC are generally quite low. This implies that no incentives exist for consumers to conserve water. Implementing metering devices, like one in Abu Dhabi has a successful story. The daily consumed water per capita in liters (l/d.Ca) is about 260 l/d.Ca when metered, and 1,400 l/d.Ca when not. Similarly, Reference 1 shows that in 2009, the Qataris

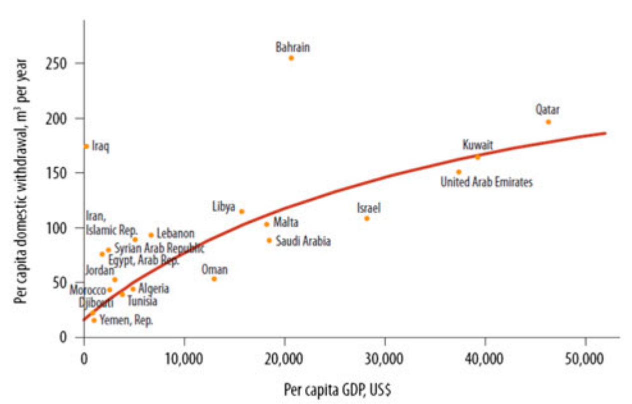

Fig. 10. Relation between per capita domestic water withdrawals and GDP per Capita [1,4].

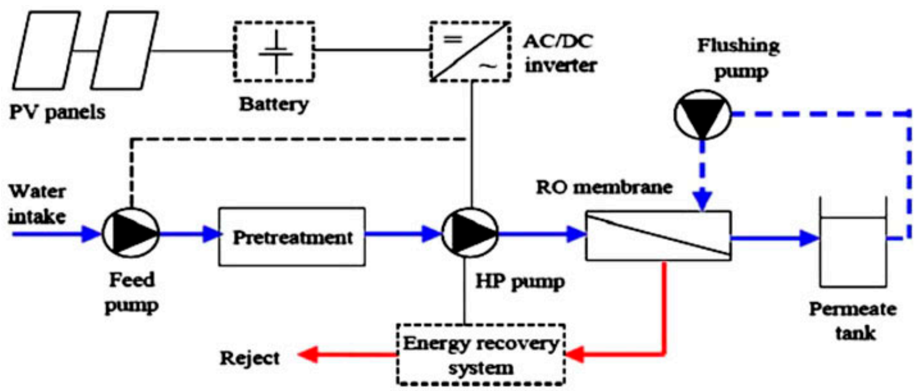

Fig. 11. Direct solar to EP generating PV operating SWRO desalination system [11].

consumed 1,200 l/d.Ca, while expatriates consumed 150 l/d.Ca, because the water is free for Qatari households and low-cost for non-Qatari households (less than 1/3 of the water production cost).

This illustrates that lack of metering and giving water at low (or no) price causes water waste. Government water heavy subsidization increase the demand and places heavy burden on budgets.

The average daily water consumption per capita in the GCC is among the highest in the world. In country like Kuwait, it increased from 200 liters per day per capita (l/d.ca) in 1980 to more than 600 l/d.ca in 2010. The effective of pricing on the consumption is clear from Abu Dhabi and Qatar cases.

Governments focus on water supply side, mainly adding more desalination plants while demand side is almost unaccounted. Besides, water losses are very high, besides the high cost of DW production, (close to $3/m^3).

4. Looking forward: solar desalination

Water scarcity in the GCC is real challenge to all GCC development, water consumption is on the rise, and managing the demand should be given the utmost priority. Even with that, new water has to fill the demand gap. Most probably, the new water would be DW.

This gap demands in the different GCC were met between 2000–2009 by adding DW capacity of 325 Mm^3/y in Qatar, 20,439 Mm^3/y in SA, 3,370 Mm^3/y in UAE, 763 Mm^3/y in Oman, 508 Mm^3/y in Kuwait, and 226 Mm^3/y in Bahrain [4].

Using of solar energy to produce DW looks very attractive as it provides free clean and secure energy source, reduces GHG emissions, minimize desalination reliance on fossil fuels, and makes desalination environmentally acceptable. Desalination by using solar energy (i.e. solar desalination) provides source of potable water sustainably.

There are many variants for solar desalination in large quantities, and include:

(1) Using photovoltaic cells to operate mechanically drove desalting systems, Fig. 11.
(2) Concentrating solar power (CSP) producing heat to drive thermal desalting system.
(3) CSP producing heat to drive power cycle producing EP that operates desalting systems.

The economic feasibility of using CSP to produce DW by thermally operated desalting system in large quantities is questionable, at least for the time being. The use of CSP for this purpose is not straight forward, at least economically, as is illustrated by the next simple examples.

The most reliable and used CSP type collectors is the Parabolic trough collector (PTC). The aperture area of the PTCs producing one Mega Watt thermal (MWt) is about 2,000 m^2, and needs about 8,000 m^2 land area. Suppose these collectors are used to desalt seawater by thermally operated desalting unit of 10 Gain ratio (GR), as shown in Fig. 12 by using MSF unit and in Fig. 13 by using TVC/ME unit. The GR is the ratio of DW output (say in kg/s) per unit steam supplied (also in kg/s) to the desalting unit. Another expression used to rate the desalting unit is performance ratio (PR). The PR is the DW output by supplying 2,330 kJ thermal energy input to the desalting unit. The values of both GR and PR are very close, and for GR = 10 (typical value for GR in currently operating MSF and TVC/ME), the specific thermal energy is 233 kJ/kg of DW. Mechanical pumping energy is also needed (14.4 kJ/kg for MSF or 7.2 kJ/kg for TVC/ME), which requires thermal energy input of 43.24 kJ/kg for MSF or 21.6 kJ/kg for ME. So, the PTC solar

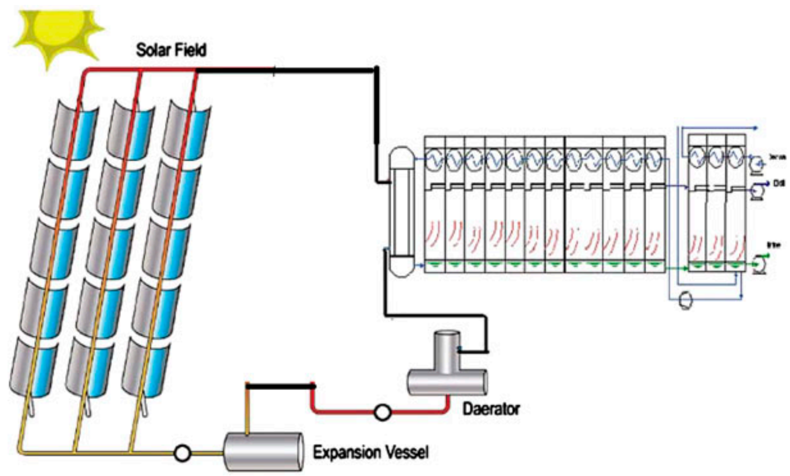

Fig. 12. Schematic diagram of solar operated MSF desalination system, using CSP collectors [11].

collectors of 2000 m^2 aperture area producing 1 MWt would generate DW output equal to 3.62, and 3.93 kg/s from MSF and TVC/ME desalting units, respectively when both have 10 GR.

High-energy efficient TVC/ME unit of GR = 16 can be built when supplied by steam at 10 bar or more, [12], from the same 2,000 m^2 aperture area of PTC collector, and thus, the specific thermal energy input would be 145.63 kJ/kg, and by using 21.62 kJ/kg pumping energy, the produced DW from 1 MWt is 5.98 kg/s, see Table 5. The DW daily output when the solar collectors produce its nominal output for 6 h, and when the desalting unit operate at full load for 24 h from the MSF of 10 GR, and from TVC/ME of 10 and 16 GR are calculated and given in Table 5.

If the same solar collectors were used to produce EP, its output would be 333 kW. This power can operate mechanically driven desalting system like SWRO, shown in Fig. 14, consuming 5 kWh/m^3 or Mechanical vapor compression (MVC), shown in Fig. 15, consuming 8 kWh/m^3. The SWRO would produce 18.3 kg/s (66.6 m^3/h or 1598.4 m^3/d when operated for 24 h), and the MVC would produce 11.4657 kg/s (41.66 m^3/h or 999.9 m^3/d when operated for 24 h). The SWRO

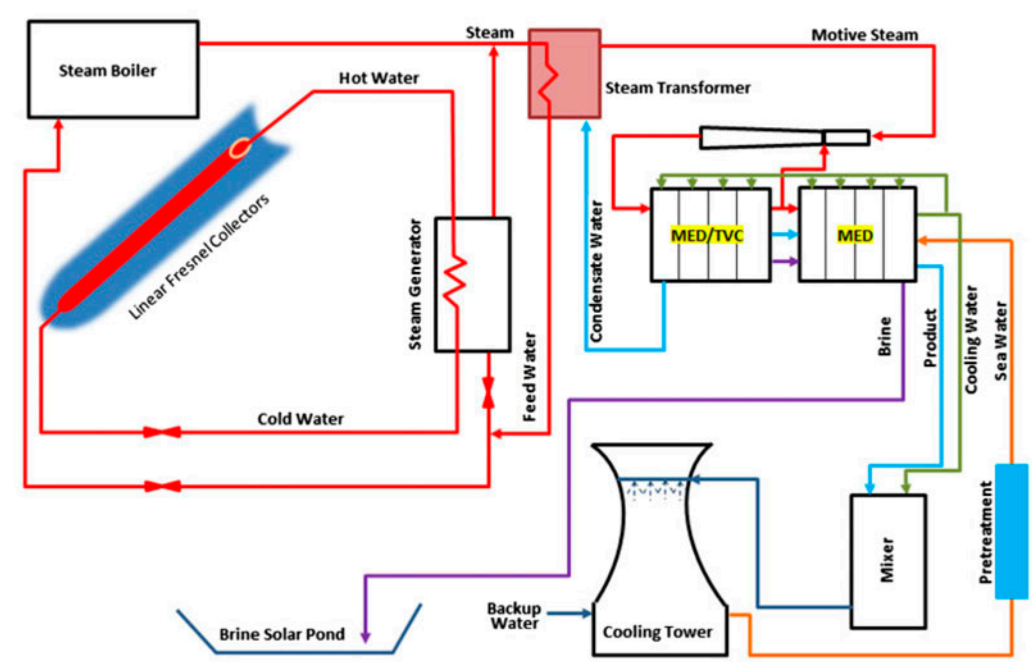

Fig. 13. Schematic diagram of solar operated TVC/ME desalination system, using CSP collectors [11].

Table 5
Comparison of desalted water obtained from PTC of 1 MWt capacity, when different desalting systems are used. These units include MSF unit of GR = 10, and TVC/ME of GR = 10, and Gr = 16, SWRO of 5 kWh/m^3 energy consumption and MVC of 8 kWh/m^3 energy consumption

Items	10GR/TVC	MSF	16GR/TVC	SWRO	MVC
Consumed thermal energy in, kJ/kg	233	233	145.63	NA	NA
Thermal energy equivalent to pumping in, kJ/kg	21.62	43.24	21.62		
Total consumed thermal energy in, kJ/kg	254.62	276.24	167.25	54.05	86.41
DW output in kg/s from 1 MWt	3.93	3.62	5.98	18.5	11.57
DW output in m^3/d from 1 MWt	14.14	13.03	21.53	66.6	41.66
DW output in m^3/d from 1 MWt for 24 h	339.33	312.77	516.61	1598.4	999.9
DWoutput in m^3/d from 1 MWt for 6 h	84.83	78.19	129.15	399.6	250.0
Collector area in m^2/(m^3/d)	23.58	25.6	15.49	5.0	8.0
Collector area required to produce 4,546 m^3/d	107,179	116,281	70,399	22,753	36,371
Solar collectors cost required to produce 4,546 m^3/d in $M	62.16	67.44	40.83	13.20	21.1
Solar energy PP cost for energy supply for 4,546 m^3/d in $M	NA	NA	NA	26.39	42.19

output is about 5.11, 4.71, and 3.1 times that of MSF and TVC/MED when the GR is 10 and 16, respectively, and by using the same PTC area. The MVC output is 3.2, 2.94, and 1.93 times that of MSF and TVC/MED when the GR is 10 and 16, respectively.

The problem is much worse, as the number of hours per day when the solar collectors are giving its nominal thermal output is less than 6 h, and not 24 h as calculated before. This gives an average daily desalted water output from solar energy of 1 MWt output as 399.6 m^3/d from SWRO, and 250 m^3/d from MVC when the solar collectors operate power Rankin cycle; and 129.15 and 84.83 m^3/d from TVC-ME having GR equal to 16 and 10, respectively, and 78.2 m^3/d from MSF, when the solar collectors directly operate the MSF and TVC/ME system. These numbers give the collector area in square meters required to produce one DW cubic meter per day (m^2/(m^3/d) when the collectors produce its nominal capacity for 6 h as 5 m^2/(m^3/d) for SWRO, 8 m^2/(m^3/d) for MVC, 15.49 m^2/(m^3/d) for TVC-ME of 16 GR, 23.58 m^2/(m^3/d) for TVC-ME of 10 GR, and 25.58 m^2/(m^3/d) for MSF of 10 GR.

The cost of PTC and its heat transfer fluid is $1.160 M/MWt, or $580/$m^2$ collector area, see Fig. 16, [13]. So, the cost of the required collectors to produce one MIGD (4,546 m^3/d) is $13.2 M for SWRO, $21.1 M for MVC, $40.83 M for TVC/ME of 16 GR, 62.16 M for TVC/ME of 10 GR, and $67.44 M for MSF. It is noticed the solar power plant (SPP) cost is almost double the cost of collectors used in that plant. So, the capital costs to produce one MIGD in the cases of SWRO and MVC are almost double that of the solar collectors; and the capital cost for solar part producing energy for the desalting units (not including the desalting units itself) are $26.39 M for SWRO, and 42.19 M for MVC, 40.83 for TVC-ME of 16 GR, 62.16 M for TVC-ME of 10 GR, and 67.44 M for MSF systems.

The cost of PTC is too expensive to directly produce DW. So, although the solar energy is considered

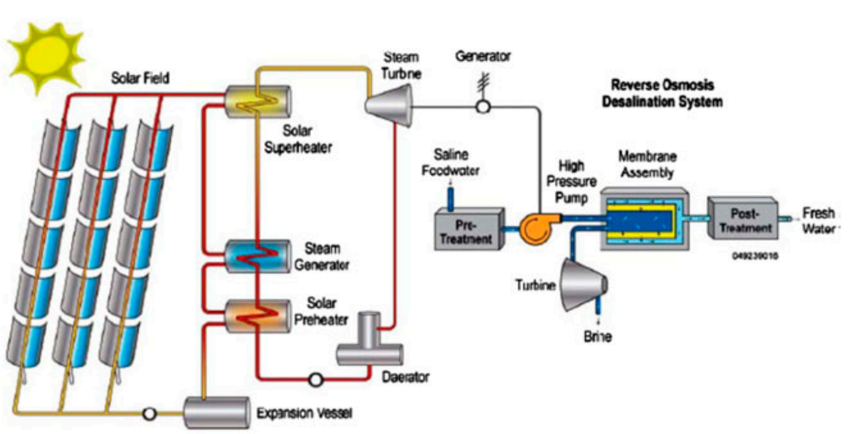

Fig. 14. Schematic diagram of the solar generating EP to operate MVC desalting system, using CSP collectors [11].

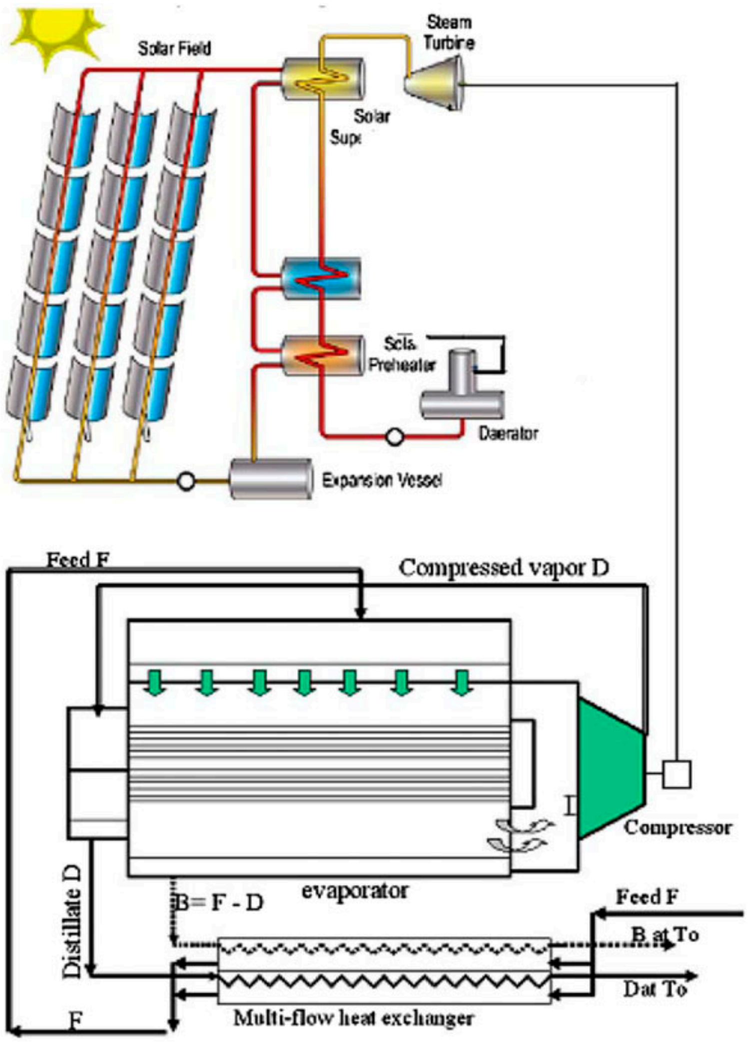

Fig. 15. Schematic diagram of the solar generating EP to operate MVC desalting system, using CSP collectors [11].

free, capturing this energy for desalting is very expensive. If lower cost collectors are chosen such as Linear Fresnel Collectors (LFC), the solar desalination economy competitiveness, besides having energy efficient desalting system (of high GR) and low-pumping energy.

The desalination group, QEERI is studying the viability of solar desalination by building an efficient TVC/ME desalting unit operated by LFC. The TVC/ME is now the preferred thermal desalting method in the GCC compared to the MSF system already used since 1960. The TVC/ME can has GR and lower pumping energy than the MSF units.

When high energy-efficient TVC/ME of GR = 16 supplied by steam at 10 bar as suggested by SIDEM desalination company, the specific thermal energy input is 145 kJ/kg of DW, and the pumping energy is 7.2 kJ/kg (requires 21.6 kJ/kg thermal energy), the 1 MWt would produce 13.93 kg/s (50.16 m^3/h), and for 6 h/d operating collectors at nominal capacity, the daily output would be 301 m^3/d.

The above calculations show that CSP producing EP that operates SWRO or MVC may be the only viable option to produce DW by solar desalination. This type of SPP can provide the needed EP in response to demand (despatchable) by using thermal energy storage. CSP-powered desalination is expensive today, but significant efforts are underway to make CSP economically competitive.

In most of GCC, DW is produced in CPDP producing both EP and DW, and using MSF and TVC/ME desalting systems. Now, the SWRO should replace both the MSF and TVC/ME systems as the SWRO is more energy efficient, and does not need to be coupled with thermal power plants in CPDP. It is just operated by electrical energy.

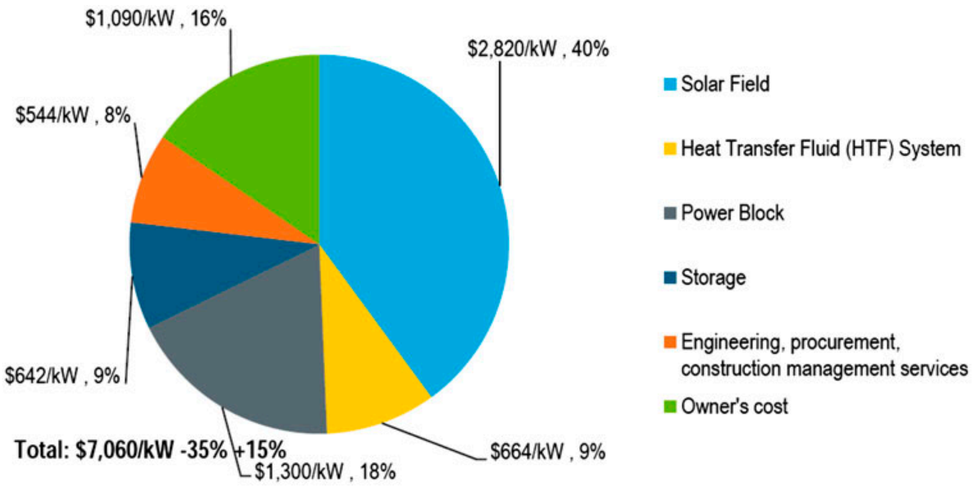

Fig. 16. Capital cost breakdown for a trough CSP plant with storage [13].

Increased RE use will significantly reduce CO_2 emissions. Generating gigawatt hour (GWh) of electricity using oil produces can consume up to 3 GWh of thermal energy. By knowing that 1 ton of fuel oil produces 42,000 MJ, the 3 GWh thermal energy needs 257 tons of oil to produce. This generates 943 tons of CO_2. Similarly, using Natural gas that produces 54,000 MJ thermal energy/ton, the 3 GWh needs 200 tons of Natural gas (NG). This generates 550 tons of CO_2. In contrast, to generate the same amount of electricity, CSP produces only 17 tons of CO_2 [4]. This vast difference will apply not only to desalination but also to EP sector since large scale solar desalination will not be done in isolation.

4. Conclusion

Qatar water problem is illustrated. The demand for fresh water cannot be solved by just adding new desalting seawater units operated by NG. This deteriorates the air and marine environment and does not present sustainable solution for the ever rising water demand. Water demand management should be given the utmost priority. The heavy government subsidizes for water resulting of low (or no) water prices promote high consumptions. Losses from water supply and waste water should be minimized as it currently presents more than 30% of potable supply water and raises the water table in Doha. Treated waste water shoulder be considered as water source for different uses, other than drinking and cooking to reduce the water demand on DW. It should be treated to potable condition and used for replenishing the heavy exploited ground water. With all efforts to reduce the water consumption and using treated waste water to secure some of the demands, a water demand gap will still exist that should between satisfied by desalting seawater. Desalting seawater by solar energy (i.e. solar desalination) provides sustainable water supply. Although solar desalination is still expensive, the prospect of using low costume solar collectors such as LFC exists. Several variants of solar desalination werewolf presented, with their initial capital cost. It was shown that using CSP to produced power that operates SWRO is the most economically competitive solution.

Abbreviations

CPDP	—	cogeneration power desalting plants
CO_2	—	carbon dioxide
CSP	—	concentrated solar power plant
DW	—	desalted water
GCC	—	gulf cooperation council
GDP	—	gross domestic product
GW	—	groundwater
LFC	—	linear Fresnel Collector
ME	—	mechanical energy
MENA	—	middle East and North Africa
MSF	—	multistage flash
MVC	—	multivapor compression
PTC	—	parabolic trough collector
PV	—	photovoltaics
SWRO	—	seawater reverse osmosis
TVC/ME	—	thermal vapor compression/multi-effect
TWW	—	treated wastewater

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