

Energy-Water Nexus in UAE: The Role of RE in Power and Water Desalination Production

**Workshop on Building Capacity on Energy-Water Nexus:
Renewable energy
ESCWA, Beirut, July 11-12, 2017**

Toufic Mezher

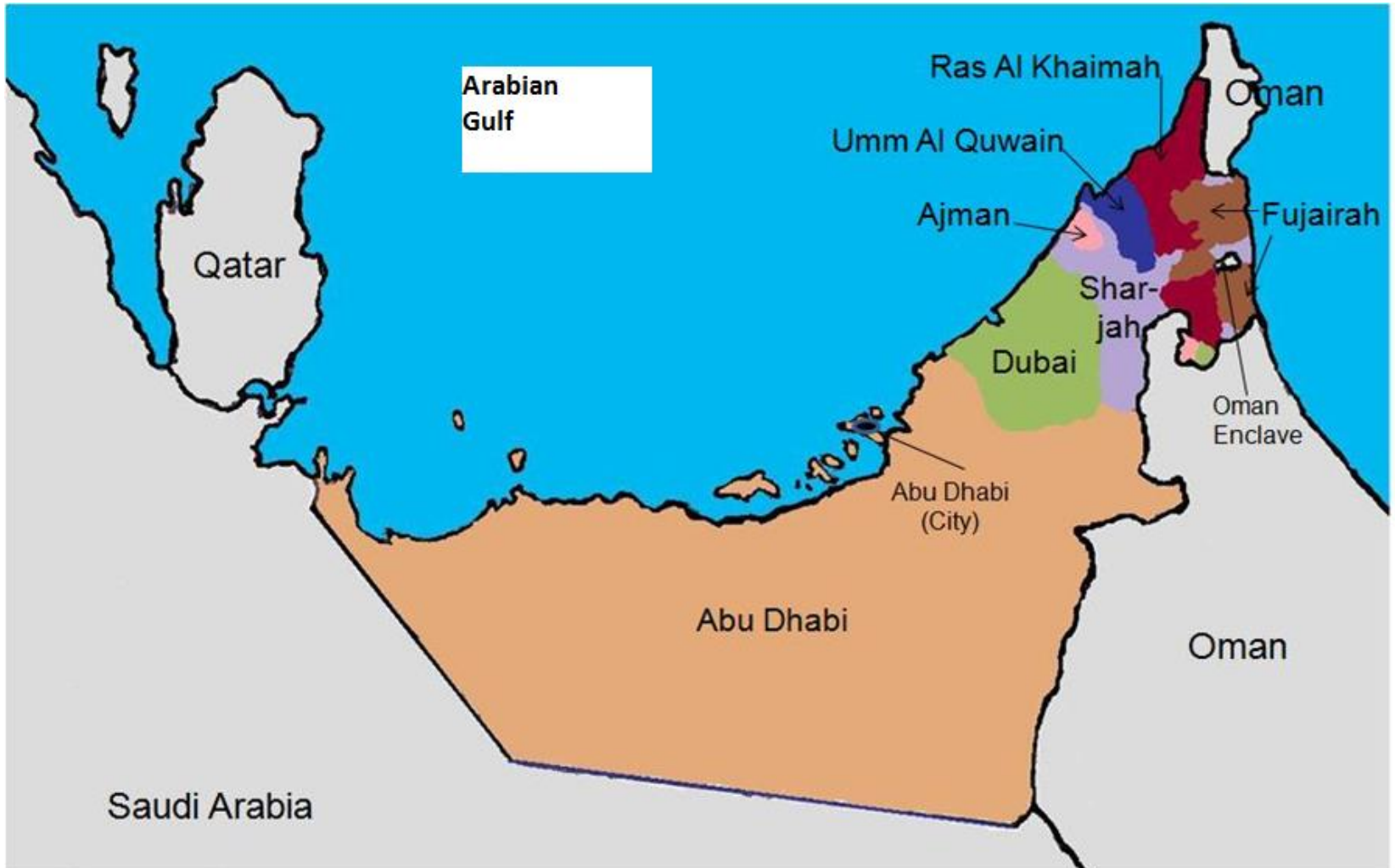
Professor, Department of Industrial and Systems Engineering

A Part of Khalifa University of Science and Technology

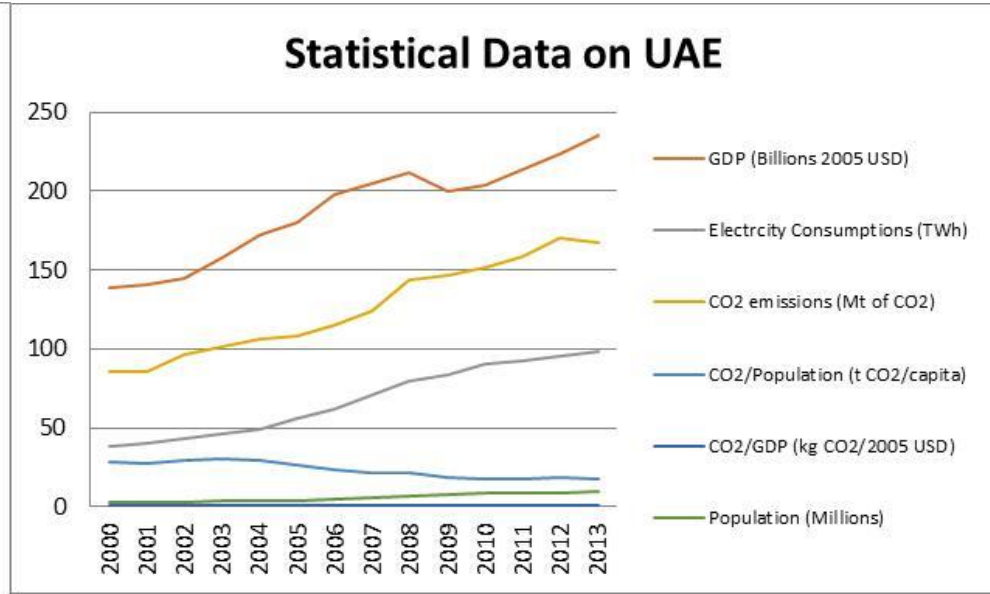
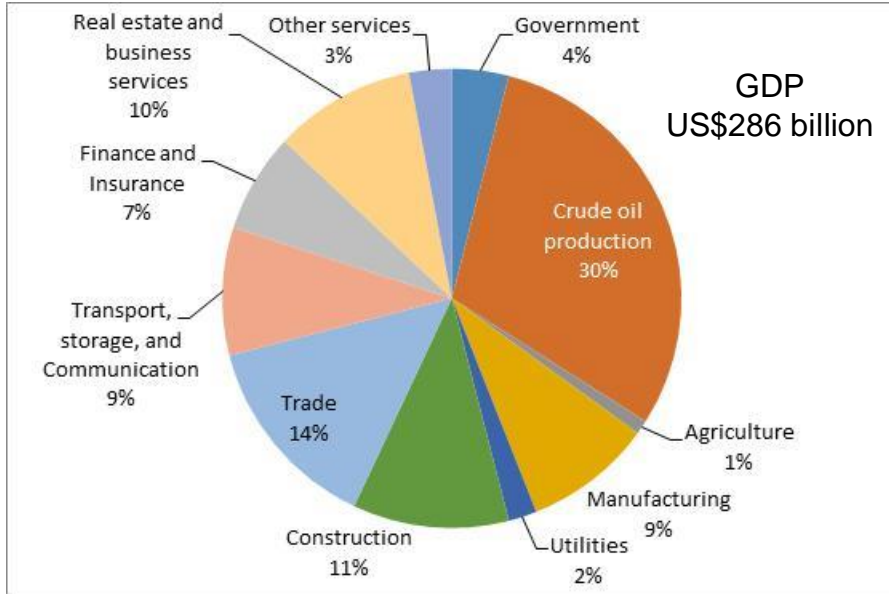
Email tmezher@masdar.ac.ae

<http://www.masdar.ac.ae>

Country Brief United Arab Emirates

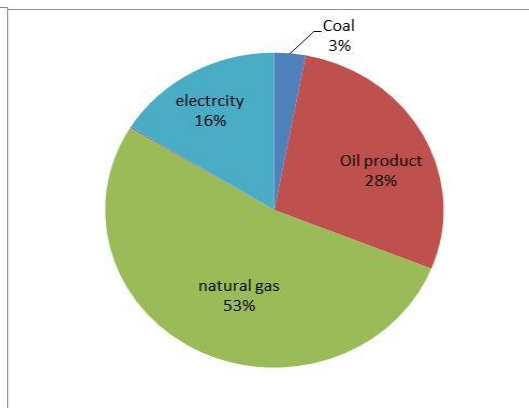
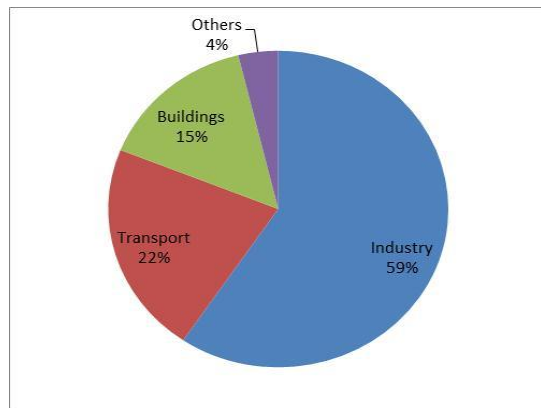


Country Brief



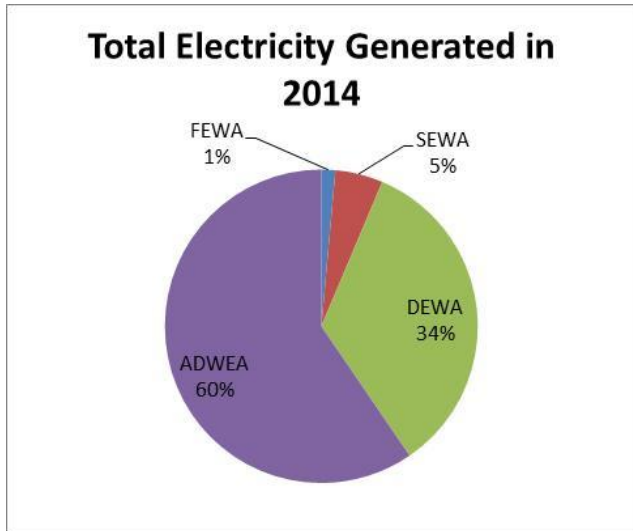
UAE Economic Profile in 2010 (Source MOE, 2012)

Economic and Energy Data of UAE (Source IEA)

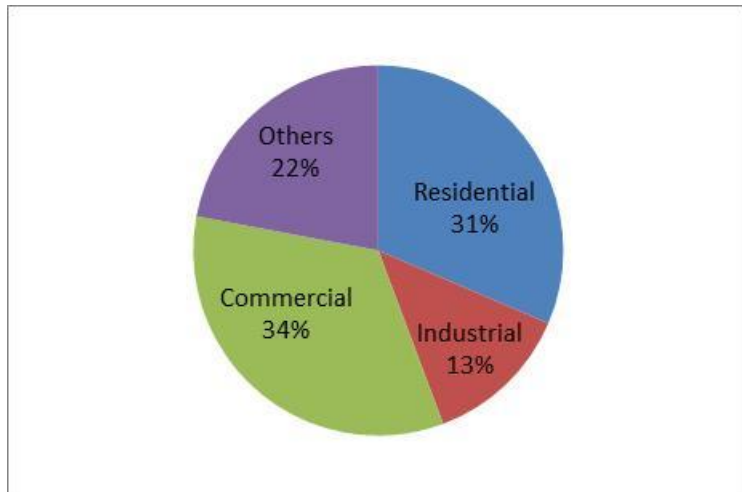


Total final energy consumption (48833 ktoe) by sector and fuel inputs in 2013. (Source IEA)

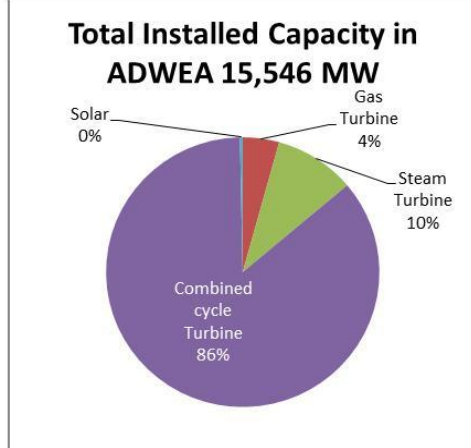
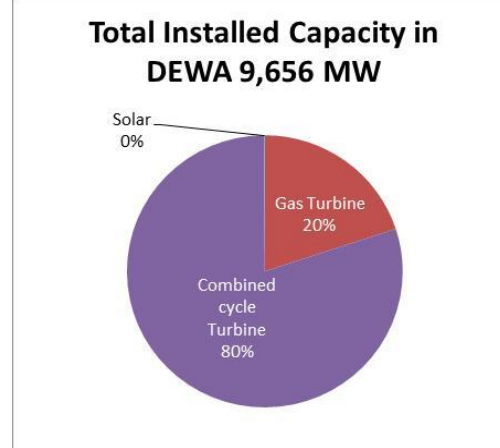
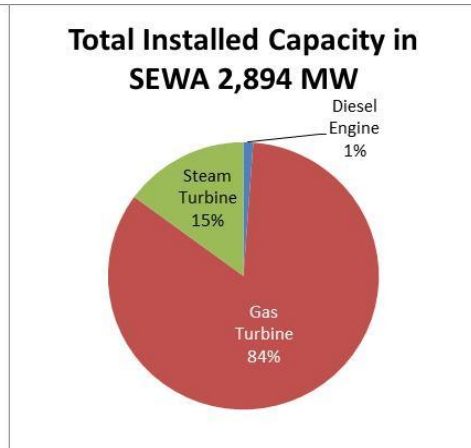
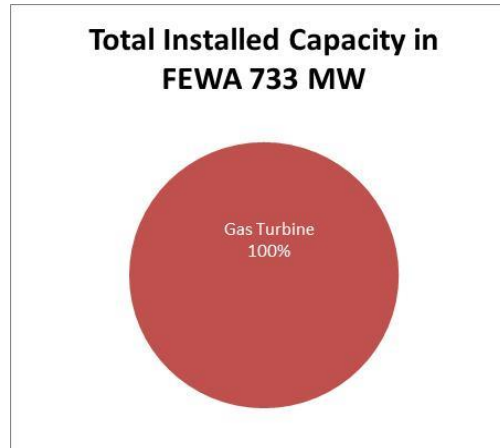
Energy sector characteristics



Share of total energy generated (116,528 GWH) by each utility in 2014



Share of Electricity Consumption by Sector in 2014

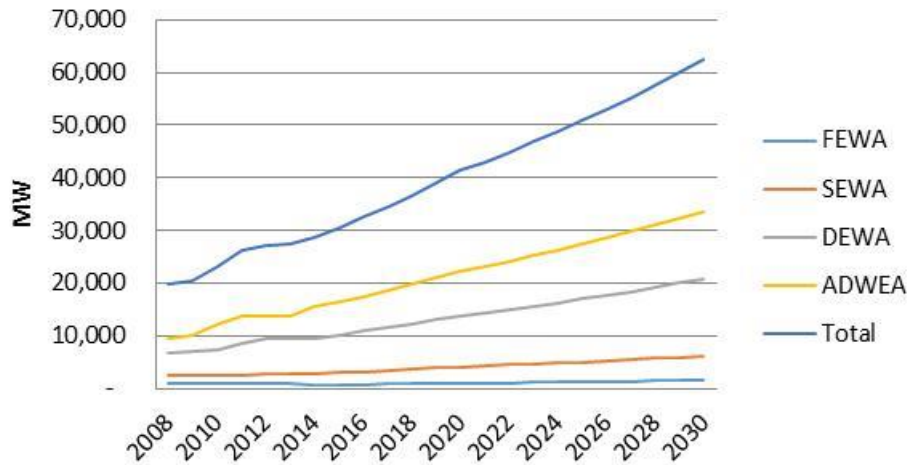


Generation Technology for the installed Capacity for each utility in 2014

(Source MOE, 2012)

Energy and Water Forecasting

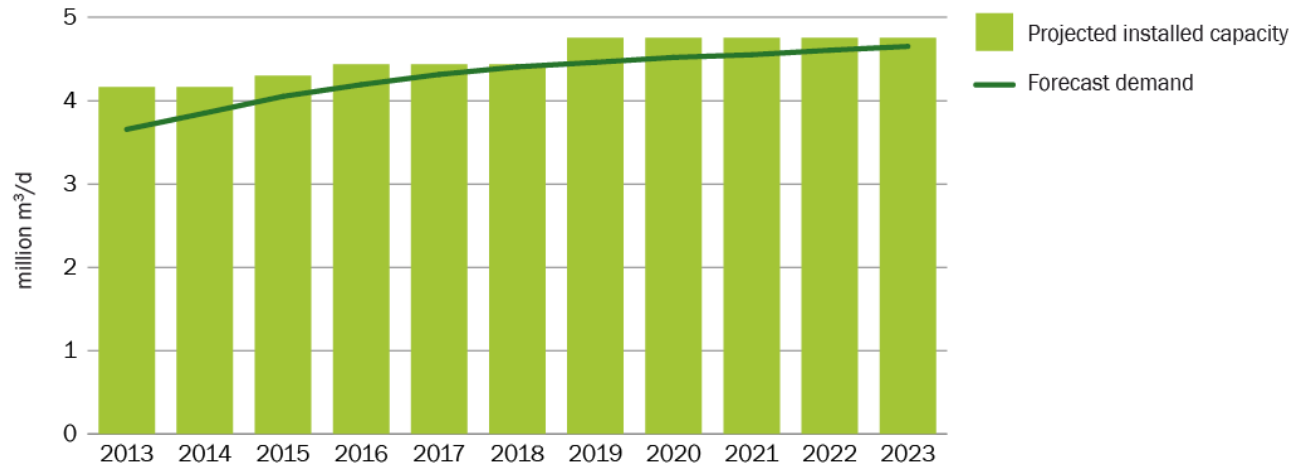
Project Power Capacity for UAE



Population (million)	2015	2020	2025
Urban	8.2	9.2	10.1
Rural	1.4	1.4	1.4
Total	9.6	10.6	11.5

Population projections, 2015–2025
 Urbanization Prospects: The 2014 Revision, United Nations, Department of Economic and Social Affairs, Population Division (DesalData)

Projected desalinated water supply and demand in Abu Dhabi, 2013–2023



Renewable Energy Projects

Existing, Announced and Future Solar projects in UAE

		Capacity (MW)
Existing RE Power Plants	Dubai Solar PV Plant, Mohammed bin Rashid Al Maktoum 1	13
	Abu Dhabi Masdar City PV Plant	10
	Abu Dhabi Shams 1 CSP Plant	100
Announced RE Power Plants	Dubai Solar PV Plant by 2020, Mohammed bin Rashid Al Maktoum 2	200
	Dubai Solar PV Plant by 2020, Mohammed bin Rashid Al Maktoum 3	800
	Abu Dhabi Solar PV power Plants by 2020, Nour 1 in Sweihan	350
Future RE Plants	Dubai is planning to add 4000 MW of Solar PV and Maybe CSP by 2030.	4000
	Abu Dhabi is planning to add solar PV plants by 2020, Nour 2	540
Future RE Rooftop	Abu Dhabi is planning to add solar PV rooftop by 2020	500

Projected total installed capacity of Solar Projects

	Total Installed Capacity		
	2016	2020	2030
Solar PV power plants and rooftop	23 MW	2500 MW	6500 MW
Solar CSP Power Plant	100 MW	100 MW	100 MW
Total	110 MW	2600 MW	6600 MW

Projected Total Waste to Energy Projects

	2020	Total Electricity Generated (KWh)
Abu Dhabi, TAQA	100 MW	700,800,000
Dubai, Al Warsan	60 MW	420,480,000
Sharjah, bee'ah	35 MW	245,280,000
Total	195 MW	1,366,560,000

Source: Renewable Energy Policies Case Study For The United Arab Emirates, 2017, ESCWA.

RE and EE Policies and related Institutions

Power Generation Announced Targets

	2020	2021	2030	2050
UAE		24 % of Clean Energy of the total energy mix		
Abu Dhabi	7% Renewables (Solar), 19% Nuclear (5.6 GW)			
Dubai	7% Renewables		25% Renewables (Solar), 7% Nuclear, 7% Clean Coal, 61% gas	75 % of energy needs will be clean sources

Demand Reduction Targets

Abu Dhabi	Enactment in 2010 of Estidama, mandatory building and landscape sustainability regulations to cut energy and water consumptions by one third and pricing reforms
Dubai	Establishment of 30 % demand reduction target by 2030 through a mix of pricing reforms, performance codes, and efficient investments (building regulations, building retrofits, district cooling, standards and labels for appliances and equipment, outdoor lighting, and change of tariffs rates)

Institutions and regulatory bodies involved in policy making and planning in UAE energy sector

	Institutions	Regulatory Bodies
UAE	Ministry of Energy	Electricity is regulated by Emirate-level institutions in Abu Dhabi, Dubai and Sharjah. The remaining are covered by Federal Electricity and Water Authority (FEWA)
Abu Dhabi	Abu Dhabi Water and Electricity Authority (ADWEA), Abu Dhabi Energy Authority (2016)	Abu Dhabi Regulation & Supervision Bureau (RSB); Abu Dhabi Water and Electricity Authority (ADWEA)
Dubai	Dubai Water and Electricity Authority (DEWA) and Dubai Supreme Council of Energy (DSCE)	Dubai Regulation & Supervision Bureau (RSB); Dubai Electricity and Water Authority (DEWA)

Source: Renewable Energy Policies Case Study For The United Arab Emirates, 2017, ESCWA.

Existing and Proposed RE Projects

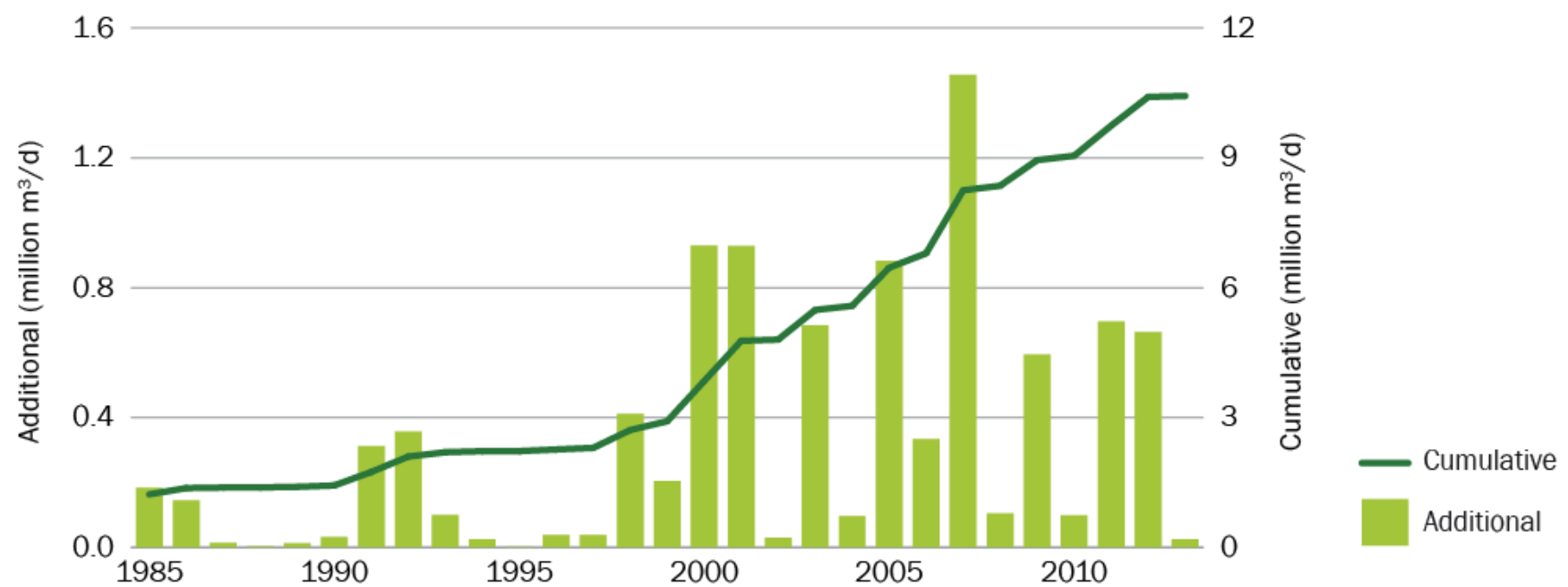
		Dubai			Abu Dhabi		
Stakeholders	Role in the value chain	DEWA 13 MW	DEWA 200 MW	DEWA 800 MW	Masdar 10 MW	SHAMS 1 100 MW	Nour 1 350 MW
Equipment Provider	Manufacturing, Assembly, and Distribution	First Solar and ABB	First Solar	BYD, JA Solar, Canadian Solar, Jinko Solar and Trina Solar	First Solar and Suntech	Abengoa Solar, First Solar, Schott Solar, and Flabeg	Jinko Solar
Developer and/or EPC	Project planning, Construction, Operation and maintenance	First Solar	ACWA Power and TSK	Masdar, GranSolar, Fotovation Renewable Ventures	Enviromena Power Systems, Masdar	Total, Masdar, Teyma, Abengoa Solar	Marubeni-Jinko Solar
Utility	Support functions: Decision making, System planning, Grid connection	DEWA and DSCE	DEWA and DSCE	DEWA and DSCE	Masdar, ADWEC	Masdar, ADWEC	ADWEC
Financier(s)	Support functions: Financial Services	DEWA	First Gulf Bank, Samba, BCB	Local and Foreign banks	Masdar	NBAD, FfW, BNP Pribas, Societe General, SMBC, MUFG	Local and Foreign banks
Financial Model		EPC	IPP and PPA	IPP and PPA	Net metering	IPP and PPA	IPP and PPA
Announced LCOE (US Cents/KWh)			5.85	2.99			2.42
Announced RE targets		5% by 2030 in 2011 and updated to 25% by 2030 in 2016			2009 7% by 2020		
Year		Commissioned in 2013	Auctioned and awarded in 2015	Auctioned and awarded in 2016	Commissioned in 2010	Commissioned in 2013	Auctioned and unofficial announcement in 2016

Source: Renewable Energy Policies Case Study For The United Arab Emirates, 2017, ESCWA.

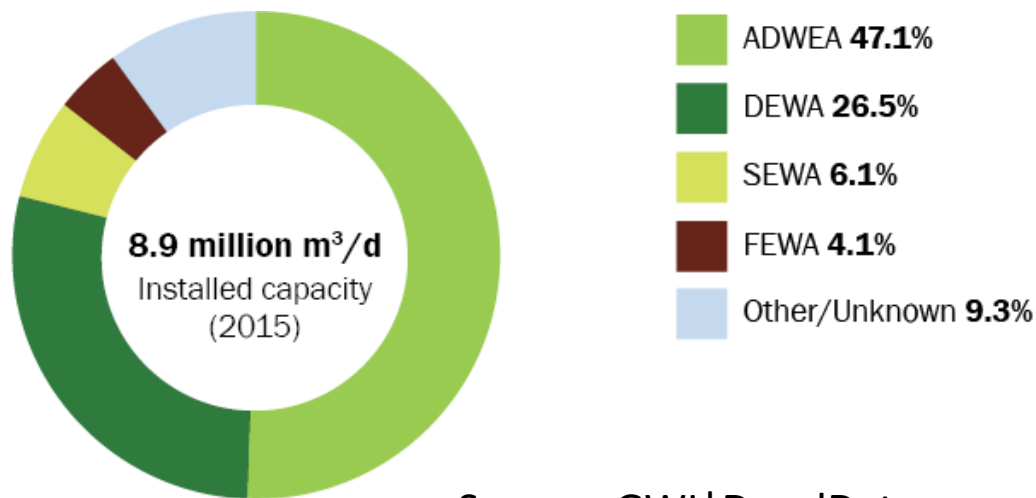
Abu Dhabi Water Supply by End User, 2012

Source (million m ³)	Agriculture, forests and parks	Home	Commer- cial	Govern- ment	Industry	Other	Total
Recycled water	138.8	0	0	0	0	0	138.8
Desalinated water	57.2	548.68	145.12	280.7	18.01	10.59	1,059.23
Ground- water	2,217.9	0	0	0	0	0	2,217.9
Total	2,413.9	548.68	145.12	280.7	18.01	10.59	3,415.93

Source: Government of Abu Dhabi (GWI | Desaldata)



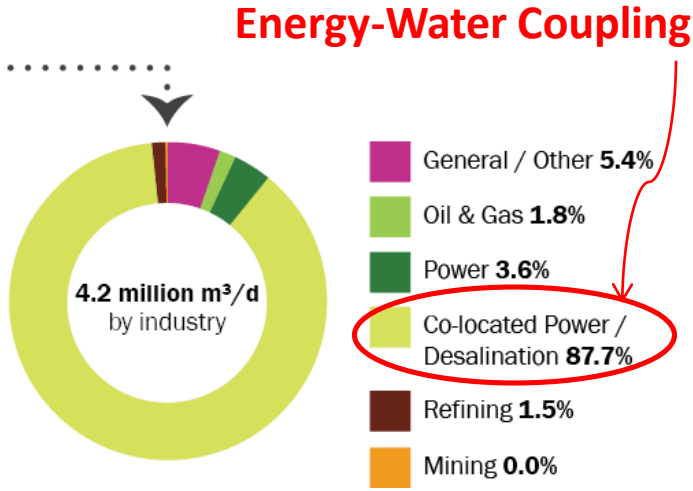
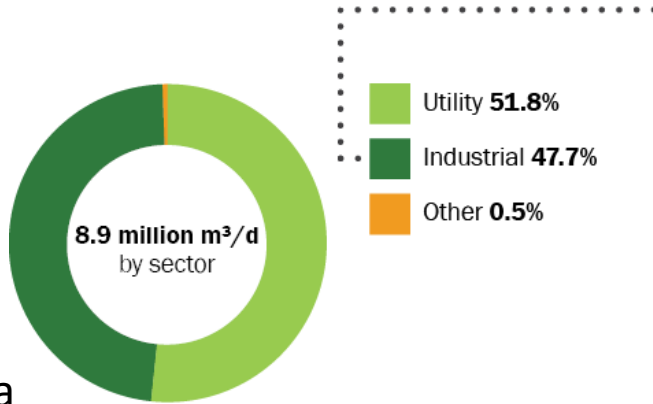
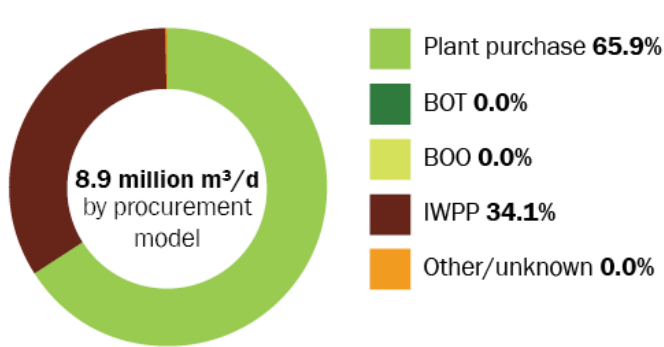
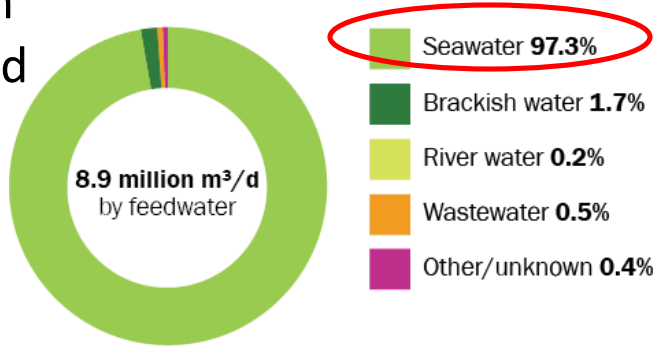
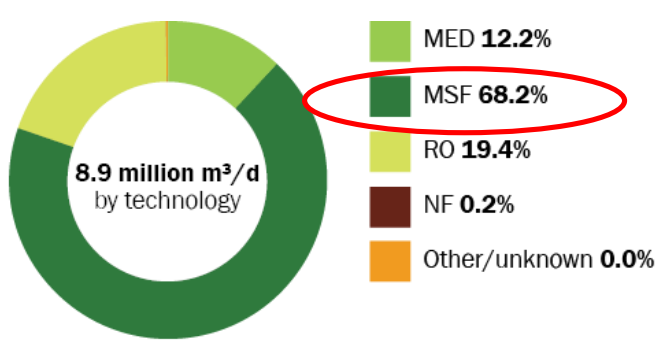
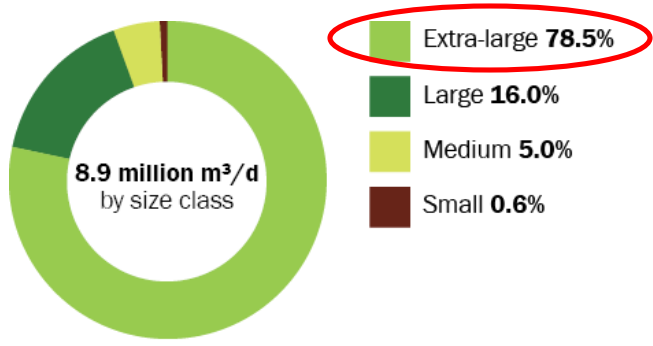
Annual cumulative and additional contracted capacity in the United Arab Emirates, 1985–2013



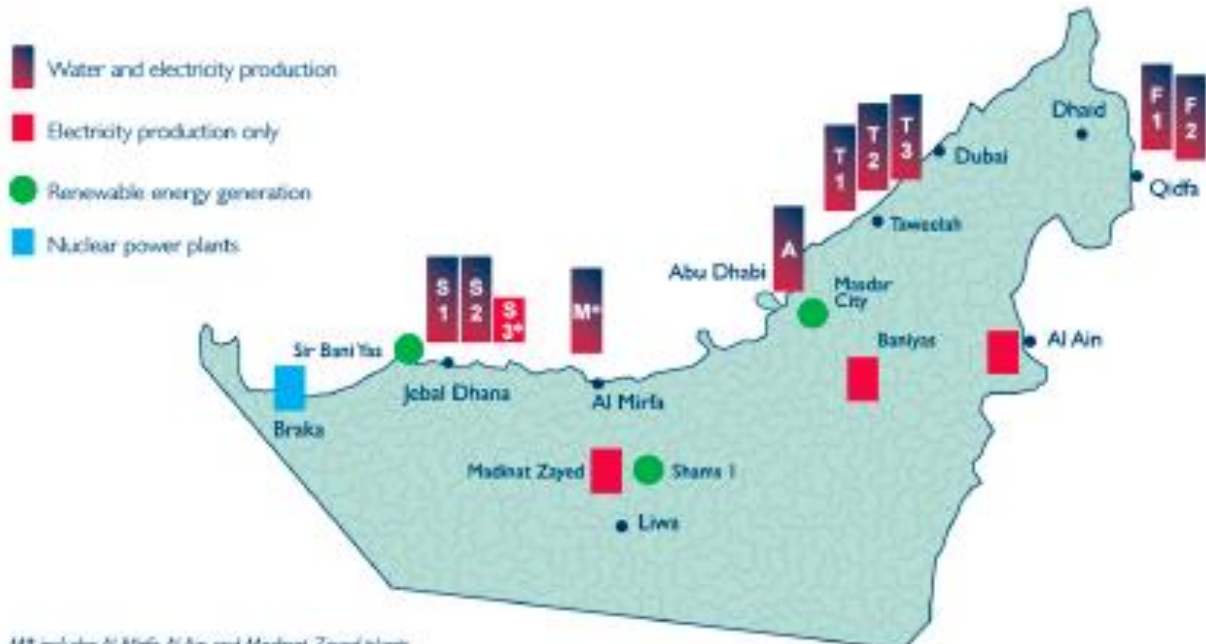
Installed capacity by off-taker, 2015

Source: GWI | DesalData

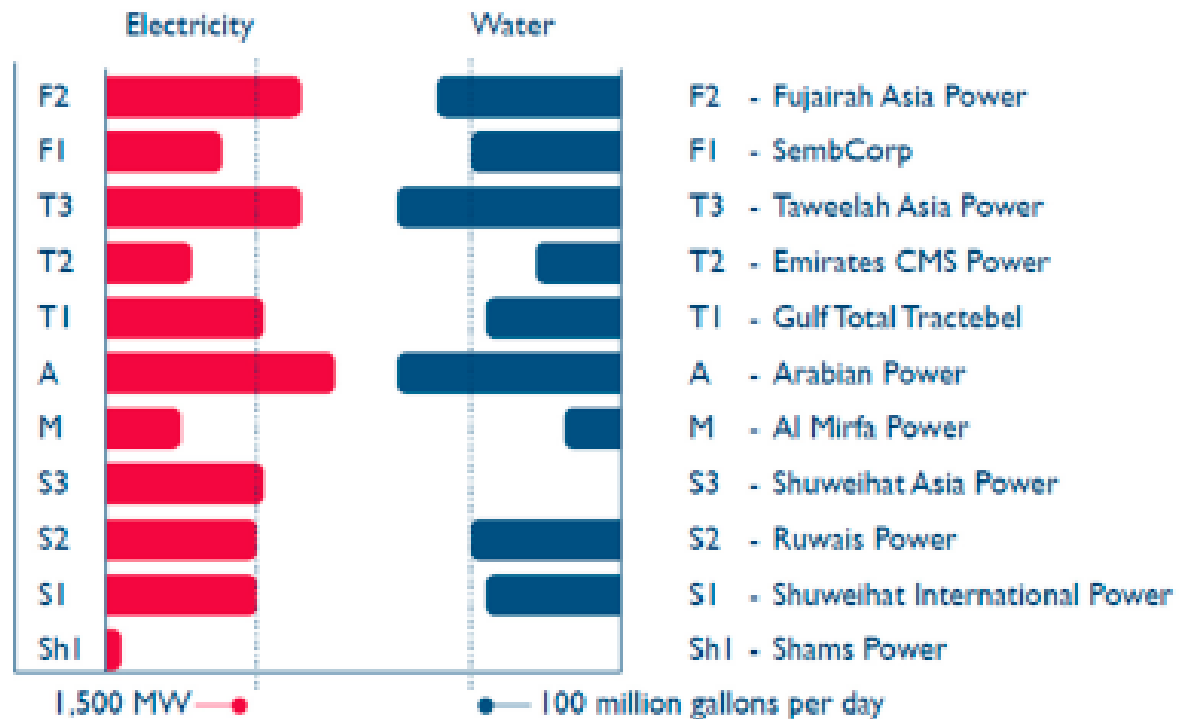
Profile of cumulative installed desalination capacity in the United Arab Emirates, 2015



Source: GWI | DesalData



M* includes Al Mirfa, Al Ain and Madinat Zayed plants
 S3* and nuclear power plants* under construction



Source: Paul et al. A Review of the Water and Energy Sectors and the Use of a Nexus Approach in Abu Dhabi, Int. J. Environ. Res. Public Health 2016, 13, 364; doi:10.3390/ijerph13040364.

Plant	Client	Supplier	Contract type	Current capacity (m³/d)	Technology	Contract Year	Online Year
Taweelah B (comprises B1, B2 and B3)	ADWEA	Fisia Italmimpianti (B1 & B3)/Hitachi Zosen (B2)	IWPP/B1 & B2 procured by EPC	727,360	MSF	2005 (for last expansion)	2008
Umm Al Nar (West, East and B plants)	ADWEA	Hitachi Zosen/Doosan Heavy Industries/Veolia SIDEM	IWPP	697,597	MSF/MED	2003 (for most recent expansion)	2007
Jebel Ali M Station	DEWA	Fisia Italmimpianti	EPC	636,440	MSF	2007	2013
Al Fujairah 2	ADWEA	Veolia SIDEM/OTV	IWPP	590,980	MED/RO	2007	2010
Al Fujairah 1	ADWEA	Acciona (expansion)/ Doosan Heavy Industries	DBO (for expansion) Originally IWPP	590,980	MSF/RO	2012 (for expansion)	2015
Shuweihat 2	ADWEA	Doosan Heavy Industries	IWPP	459,146	MSF	2009	2011
Shuweihat 1	ADWEA	Fisia Italmimpianti	IWPP	454,600	MSF	2001	2004
Taweelah A1 (extension and original)	ADWEA	Veolia SIDEM	IWPP	381,864	MED/MSF	1998	2001
Jebel Ali L1	DEWA	Fisia Italmimpianti	EPC	317,800	MSF	2003	2005
Jebel Ali G	DEWA	VWS Westgarth	EPC	273,000	MSF	1991	1995

Major plants for industrial clients

Name	Client	Plant supplier	Contract type	Capacity (m ³ /d)	Industry	Technology	Contract year	Online year
Mussafah (Abu Dhabi) Steel plant Expansion	Emirates Steel Industries	Bernardinello Engineering	EPC	40,000	Metals	RO	2010	2011
Ruwais Refinery	ADNOC	Fisia Italimpianti	EPC	30,000	Refining	MSF	1998	2001
EMAL Emirates Aluminium	EMAL Emirates Aluminium	Aqua EPC L.L.C.	EPC	20,300	Metals	RO	2007	2010
Al Ruwais	ADNOC	Envirogenics	EPC	20,000	Refining	MSF	1981	1983
Al Ruwais	ADNOC	Hitachi Zosen	EPC	18,240	Refining	MSF	1993	1995

Source: GWI | DesalData

Masdar Renewable Energy Desalination Programme

- Masdar is investing in R&D and building testing water desalination 5 stations with greater energy efficiency and commercial advantage.
- The three systems were installed at the site of the Masdar Renewable Energy Desalination Programme in Ghantoot and were tested for 18 months.
- Four companies working on this programme, Veolia, Abengoa, Suez, and Mascara, evaluated the technologies of advanced reverse osmosis, while a fifth company, Trevi Systems, tested the technology of frontal osmosis.
- According to the initial results, which were demonstrated during last year's Global Water Summit, the stations are working with twice the efficiency of standard heat technologies, which are used to produce most of the drinking water in the Gulf region.

Contracted Water Desalination Plants

Project	Capacity (m ³ /d)	Technology	Plant Status
Hazardous Waste	600	RO	Construction
Masdar renewable energy II	300	RO	Construction
Masdar renewable energy III	100	RO	Construction
Masdar renewable energy IV	50	FO	Construction
Mirfa IWPP, Abu Dhabi	140,000	RO	Construction
Ras Al Khaimah IWP	100,000	RO	Construction
Total contracted capacity	241,050		

Planned Plants

Project	Capacity (m ³ /d)	Technology	Plant Status	Progress Details
Dubai solar desal pilot	0	RO	Planned	Eight bidders submitted offers by the 11 June 2015 deadline, with one bidder providing an alternative offer. Two of the bids, from Abengoa Water and Drake and Scull, respectively, were rejected. The prices on the seven approved offers are as follows: 1) HHH Construction (AED3.0m/\$0.8m); 2) Value Addition (AED4.5m/\$1.2m); 3) Al Mostajed – main offer (AED6.9m/\$1.9m); 4) ADC Energy Systems (AED6.9m/\$1.9m); 5) Al Mostajed – alternative offer (AED8.1m/\$2.2m); 6) Bilfinger Deutsche Babcock (AED8.9m/\$2.4m); 7) LMM General Trading (AED9.3m/\$2.5m).
Fujairah 3 IWPP	318,220		Planned	ADWEA has issued a request for proposals from consultants to carry out a plant layout investigation study for the site at Qidfa. The deadline for the RFP is 17 April. Responsibilities of the consultant will include assessing the potential power capacity of the site, and putting together a potential layout for the plant as a whole.
Fujairah Fresh Water SWRO	4,500	RO	Planned	FFWP has issued a request for proposals from engineering consultants to carry out specification and engineering works related to tendering, project management and construction supervision. The deadline for bids is November 12.
Jebel Ali power station SWRO	181,840	RO	Planned	A 40MIGD (181,840m ³ /d) SWRO desalination plant to be built at the site of the Jebel Ali power station in Dubai. DEWA has made tender documents available to interested engineering consultants to advise on the project. Offers must be submitted by 27 April 2016.
Layyah SWRO stage 2	22,730		Planned	A 5MIGD (22,730m ³ /d) expansion to the Layyah desalination plant, which will bring the facility up to a total capacity of 45,460m ³ /d. Six bidders had technical offers opened on 22 May 2016: 1) Aqua Engineering/Tecton; 2) Aqualyng/Acwa Emirates; 3) Fisia; 4) Metito; 5) Técnicas Reunidas; 6) Utico.
Masdar renewable energy desalination programme	100,000		Planned	More than 100 companies have submitted letters of intent to work on the project. 48 offers have been shortlisted, and Masdar plans to issue a request for proposals to approved bidders at some point in 2013.
Umm al Quwain IWP	204,570	RO	Planned	A 45MIGD (204,570m ³ /d) seawater desalination plant to be built on a privately financed basis. The offtaker will be the utility for the northern emirates of the UAE, the Federal Electricity and Water Authority (FEWA). The project supersedes the publicly funded facility that FEWA had earlier planned to be built in Ajman. Three companies submitted bids for client advisory work: CEC Consulting Engineering (Dr Saie), ILF Consulting Engineers, and Parsons Brinckerhoff. The client is expected to make a decision in November, and award a contract before the end of 2015.
Total planned capacity	831,860			

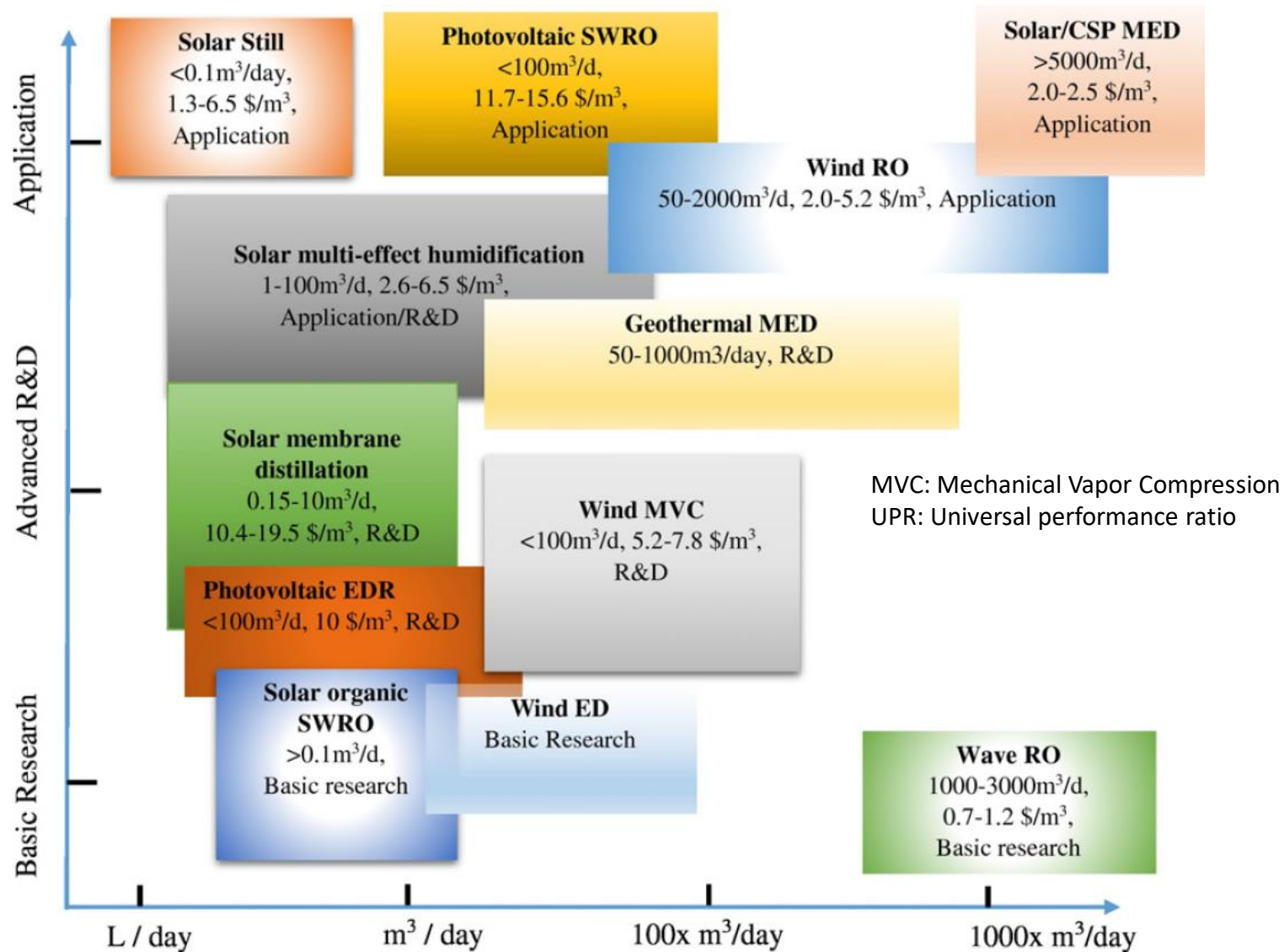


Fig. 7. Renewable energy operated desalination technologies status: Capacity, production cost & technology trend.

Source: Shahzad et al., Energy-water-environment nexus underpinning future desalination sustainability, Desalination 413 (2017) 52–64.

Thermally driven cycle's hybridization:

Readily available individually, need to hybridize to achieve UPR > 20% of TL.

RO Processes:

High performance membrane materials will take 5-10 year to be available commercially [237]

TL: Thermodynamic limit
UPR: Universal performance ratio

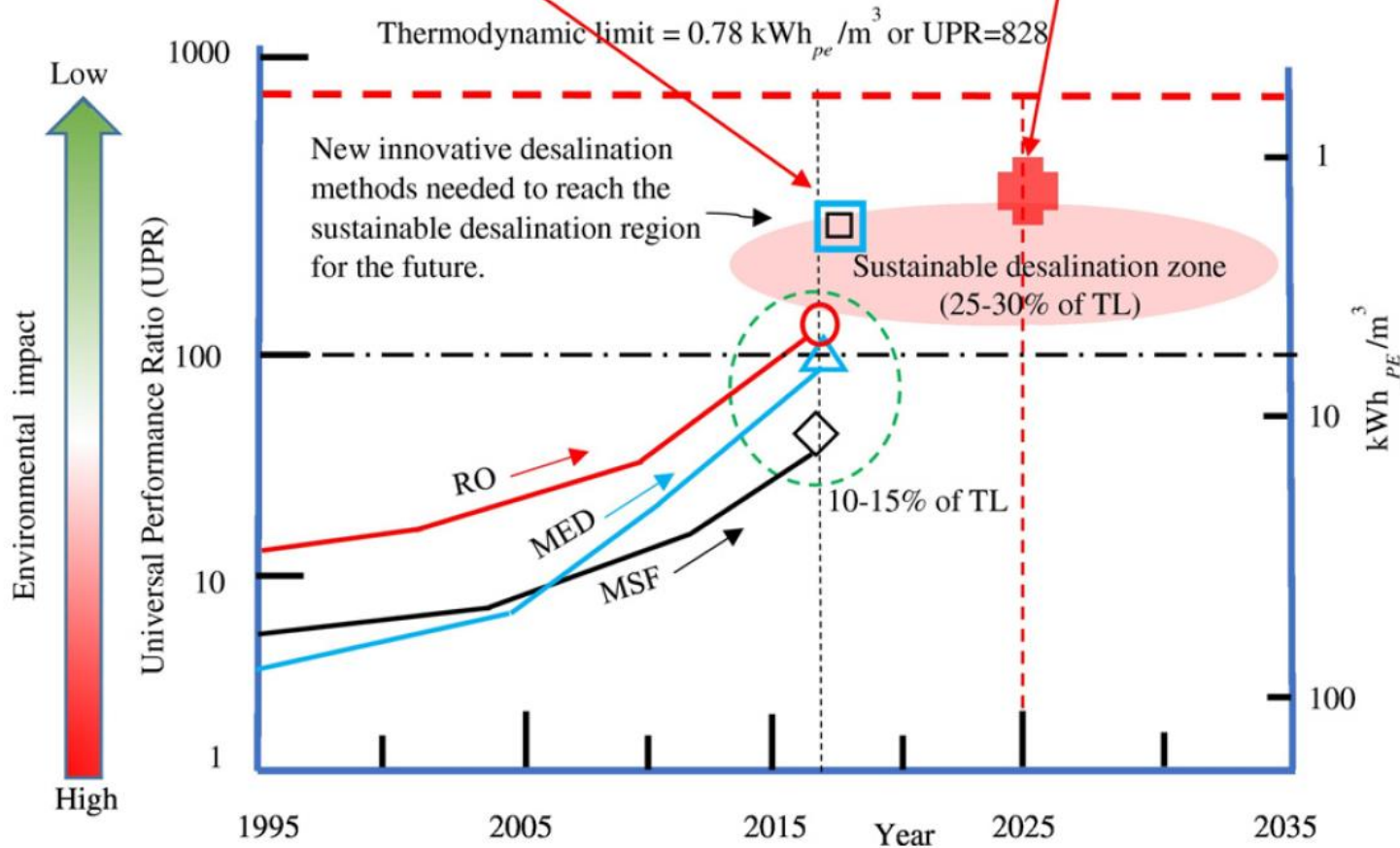


Fig. 8. Desalination technologies roadmap for future sustainability.

Source: (Shahzad et al., 2017)

Energy Water Nexus Dilemma in UAE

- Majority of existing water and power production are based on cogeneration/combines cycles:
 - Water Demand remains the same though out the year
 - Energy demand is less during the winter
 - This will lead to system inefficiency and increase the cost of water production.
 - Existing power production and thermal desalination (MED/MSF) is no longer a good option.
- RE and Nuclear power can play an important role in standalone water desalination production plants.

Thank You

