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TECHNOLOGIES TO IMPROVE ENERGY EFFICIENCY

Water-Energy Nexus Operational Toolkit : Resource Efficiency

20/02/2017

Outline

Introduction

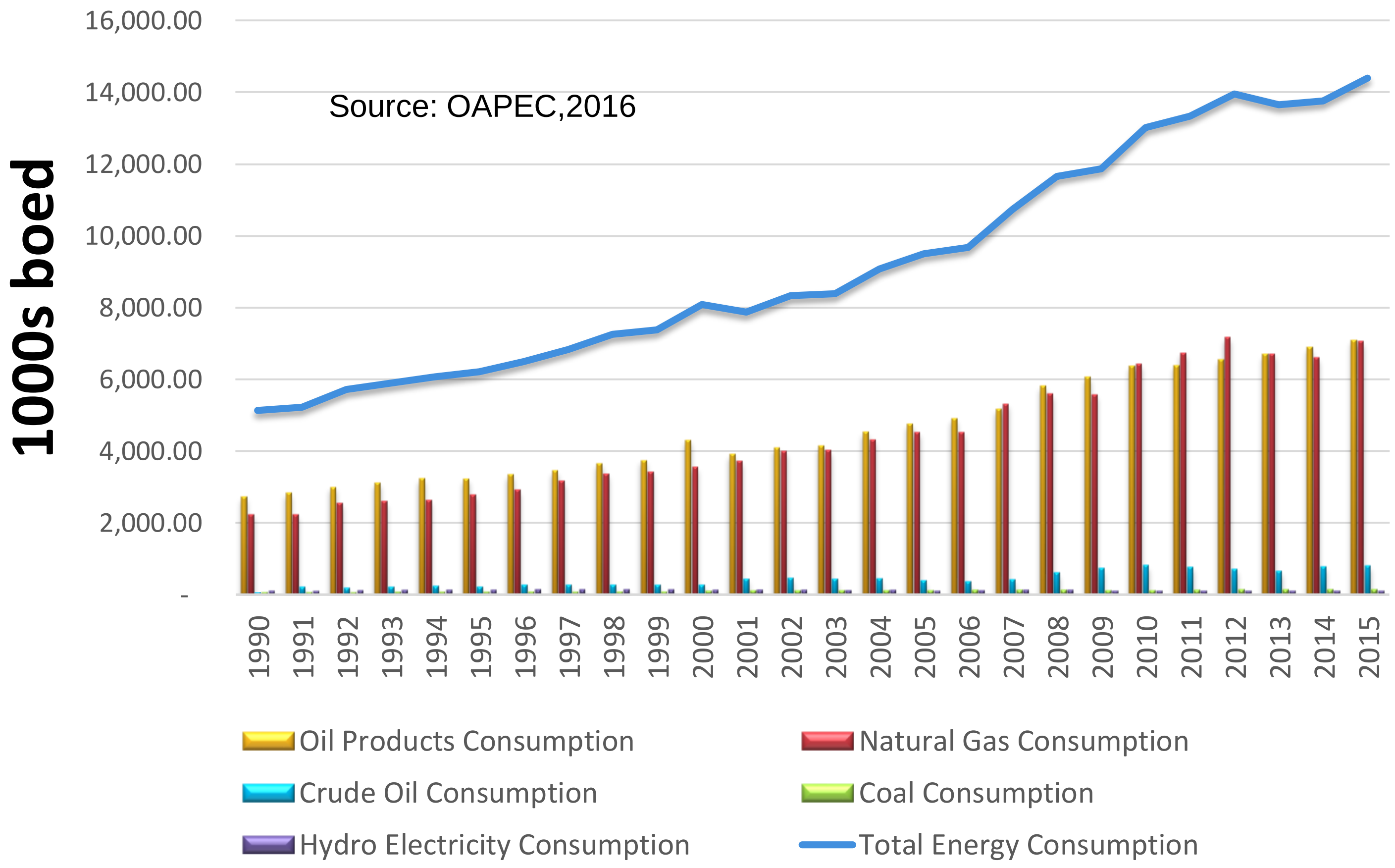
Energy efficiency in water and wastewater treatment

Energy efficiency in water distribution systems

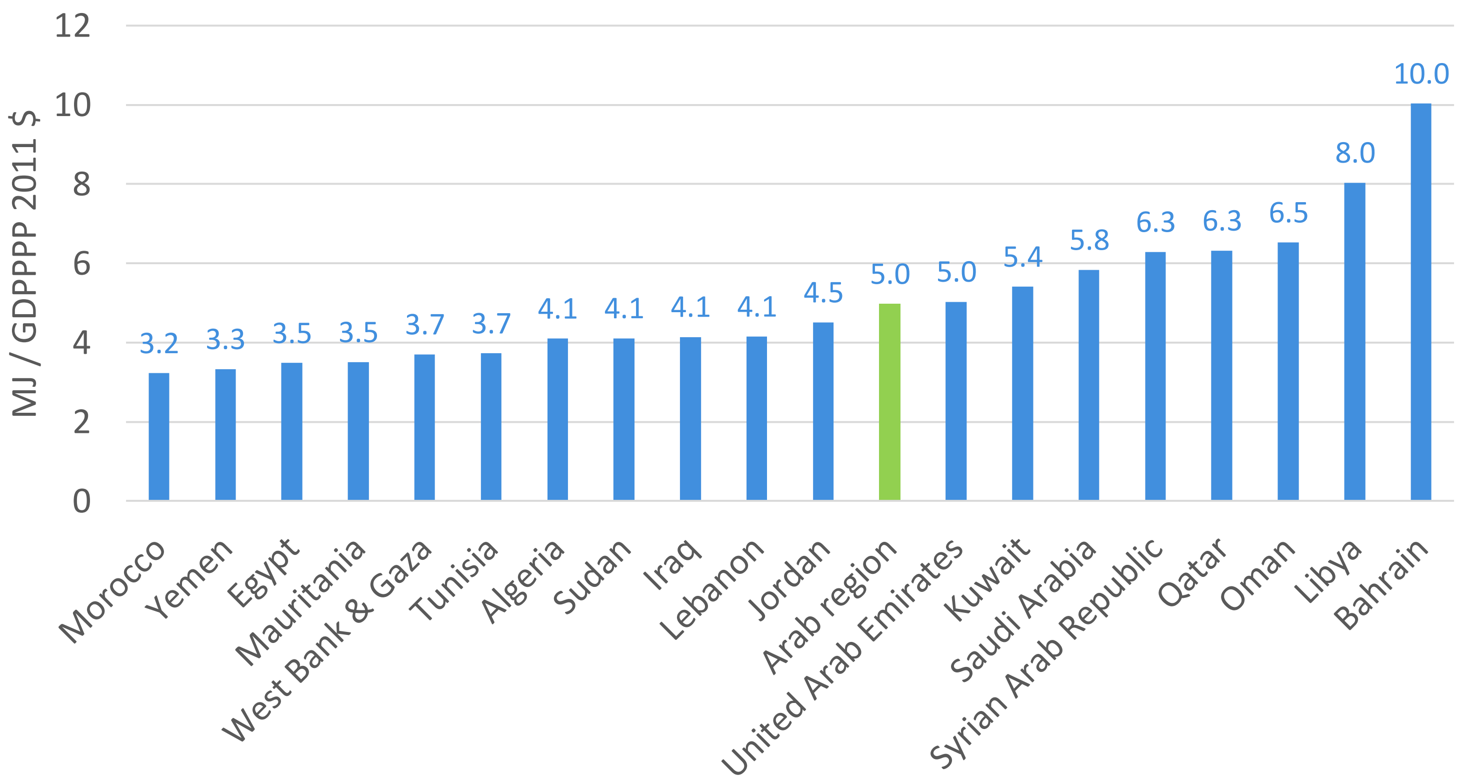
Energy efficiency in desalination

Key messages

Energy Consumption in the Arab Region



Energy intensity in the Arab countries



On a country-by-country level, the Arab region includes a range of very different economies, from low energy intensity to some of the world's highest intensity rates.

Energy efficiency in water and wastewater treatment

Energy management opportunities in the water and wastewater industries

Energy efficiency and demand response

- Data monitoring and process control
- High-efficiency pumps and motors

Emerging technologies and processes

- Membrane bioreactors
- Microbial fuel cells
- LED UV lamps

Energy recovery and generation

- Cogeneration using digester biogas
- Use of renewable energy to pump water

Source: Reekie, 2013

Best practices in water and wastewater energy management

General

- Electric motors: correctly size motors
- Electric peak reduction
- Pumps: reduce pump head

Water

- Integrate system and power demands
- System leak detection and repair
- Optimize storage capacity

Wastewater

- Manage for seasonal peaks
- Dissolved oxygen control
- Sludge: replace centrifuge with gravity belt thickener

Source: Malcolm Pirnie, Inc., 2010.

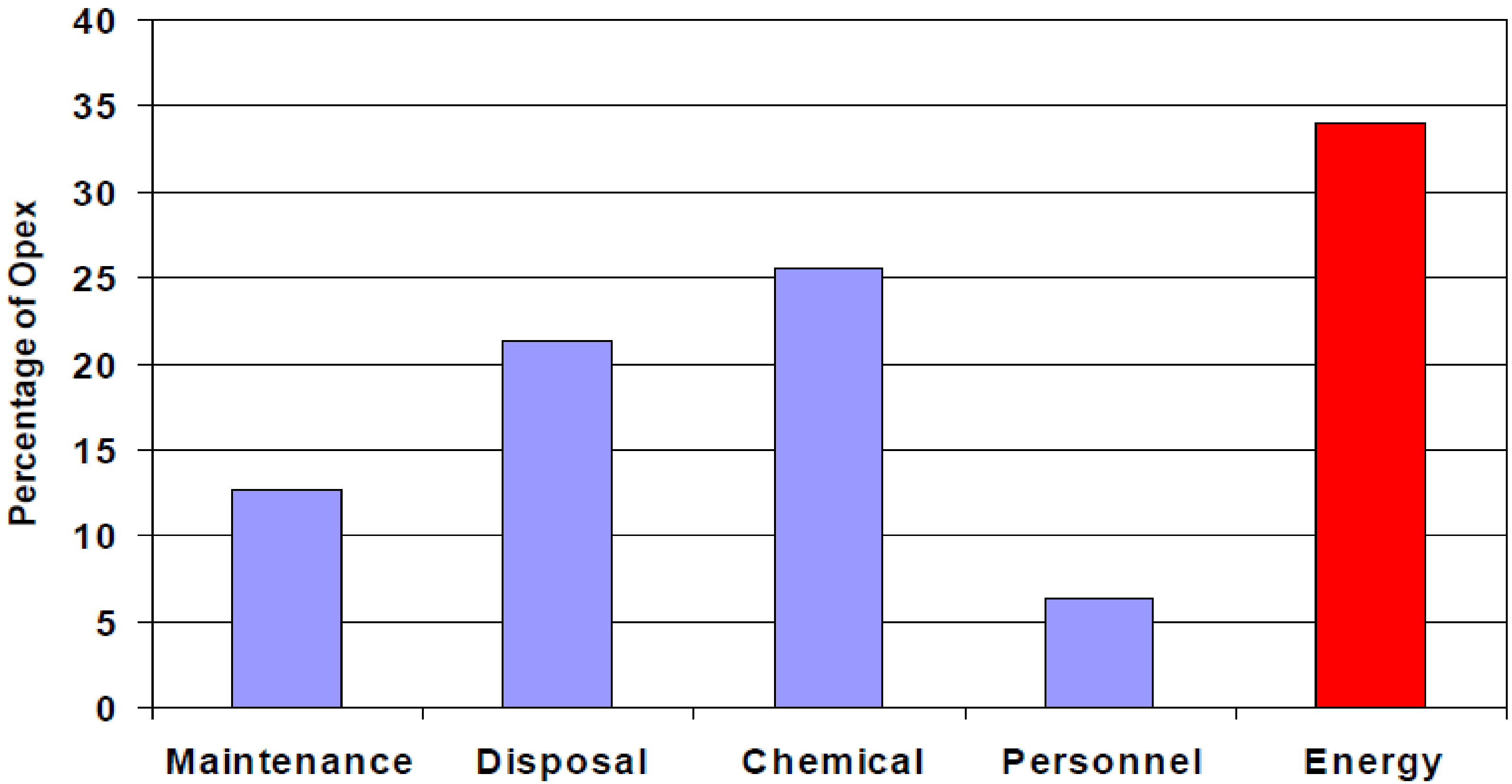
Demand Response (DR)

- Water and wastewater treatment plants good candidates for the use of DR strategies.
- Example: 30% decrease in electricity demand using DR (WWTP in Southern California).

Strategies to reduce electricity consumption from the grid at peak periods

- Load shedding/load curtailment
- Load shifting
- Switching to onsite generation
- Combination of previous three strategies

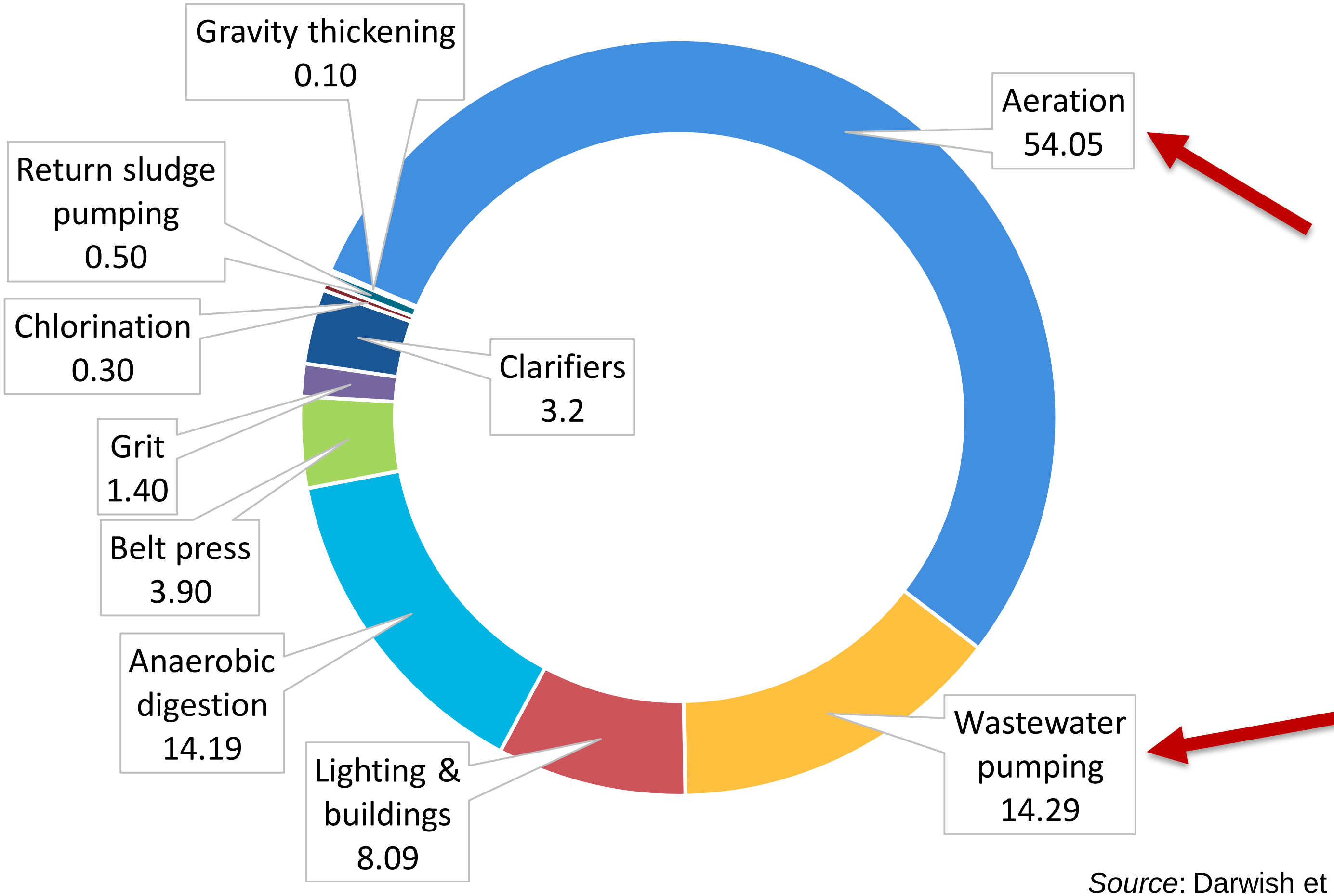
Significance of energy in wastewater treatment



Source: Husmann, 2009.

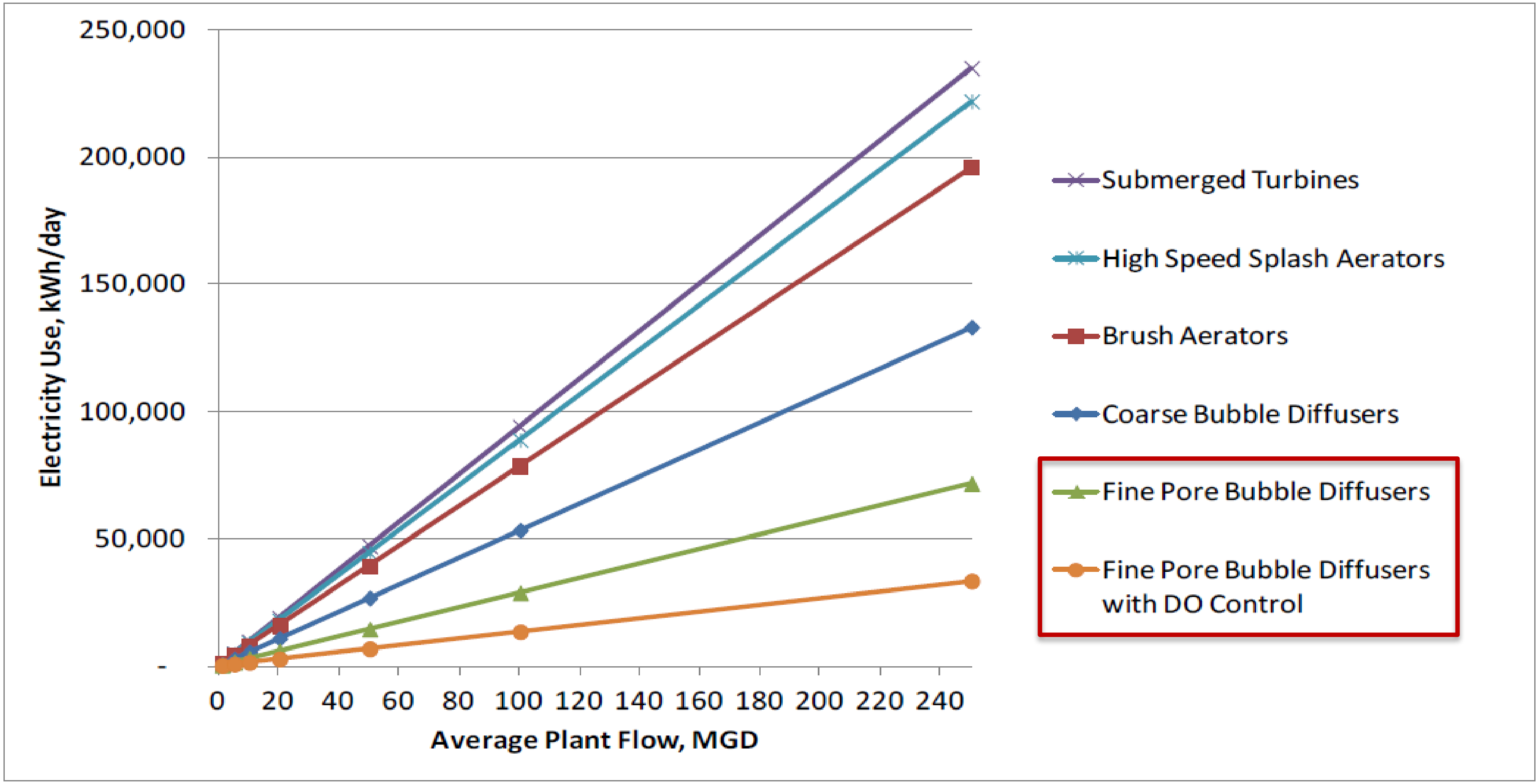
Wastewater treatment plants (WWTPs)

Percentage breakdown of typical wastewater system energy consumption



Source: Darwish et al., 2016.

Electricity use for a variety of aeration types at a range of plant flow rates



Source: Reekie, 2013.

Wastewater treatment plants (WWTPs)

Energy consumption variation by plant size and treatment type

Treatment plant size (m^3/day)	Trickling filter (kWh/m^3)	Activated sludge (kWh/m^3)	Advanced wastewater treatment (kWh/m^3)	Advanced wastewater treatment nitrification (kWh/m^3)
3,785	0.479	0.591	0.686	0.780
18,925	0.258	0.362	0.416	0.509
37,850	0.225	0.318	0.372	0.473
75,700	0.198	0.294	0.344	0.443
189,250	0.182	0.278	0.321	0.423
378,500	0.177	0.272	0.314	0.412

Source: Darwish et al., 2016.

Energy consumption variation by extent of plant capacity usage

Plant capacity	Plants operating at 80% influent capacity		Plants operating at 50% influent capacity	
Average daily flow (MGD)	Primary (source) energy (GJ/MG)	Secondary (site) electrical energy (kWh/MG)	Primary (source) energy (GJ/MG)	Secondary (site) electrical energy (kWh/MG)
1	19.6	1,629	27.2	2,263
5	15.2	1,264	22.8	1,898
10	13.3	1,107	20.9	1,741
20	11.4	950	19.0	1,584
50	8.9	742	16.5	1,377
100	7.0	585	14.7	1,220

Source: Deines, 2013.

Wastewater treatment plants (WWTPs)

Energy consumption variation by effluent quality

Treatment system	Effluent quality				Energy (1000 kWh/yr)
	BOD	SS	P	N	
Rapid infiltration (facultative lagoon)	5	1	2	10	150
Slow rate, ridge + furrow (facultative lagoon)	1	1	0.1	3	181
Overland flow (facultative lagoon)	5	5	5	3	226
Extended aeration + sludge drying	20	20	-	-	683
Extended aeration + intermittent sand filter	15	15	-	-	708
Trickling filter + anaerobic digestion	30	30	-	-	783
Activated sludge + anaerobic digestion	20	20	-	-	889
Activated sludge + anaerobic digestion + filter	15	10	-	-	911
Activated sludge + nitrification + filter	15	10	-	-	1051
Activated sludge + sludge incineration	20	20	-	-	1440
Activated sludge + advanced wastewater treatment	<10	5	<1	<1	3809

Source: Crites et al., 2014 .

Processing and disposal methods of solids

Processing or disposal function	Unit operation, unit process and treatment method	Impact on electricity use
Stabilization	Heat treatment Aerobic digestion Composting: In-vessel	Significant Moderate/significant Significant
Conditioning	Heat treatment	Significant
Dewatering	Vacuum filter Centrifuge Filter press	Significant Significant Moderate/significant
Heat drying	Multiple effect evaporator	Significant

Source: Reekie, 2013.

Anaerobic Digestion at WWTPs

Advantages

- Less energy intensive than aerobic treatment
- Generation of biogas as a byproduct (potential energy source for WWTP)

Disadvantages

- Can only treat a smaller range of water
- Usually followed by aerobic treatment during post-treatment.
- Requiring greater heat input than aerobic digestion.

Examples

- As of 2009, 64 anaerobic installations in MENA.
- As-Samra Wastewater Treatment Plant (Jordan) fulfills 80% of its electricity needs internally.
- Gabal El Asfar (Egypt) fulfills up to 65% of its power needs internally.

Wastewater treatment plants (WWTPs)

Energy recovery potential using established technologies

		Net energy: "Gap" reduction possible (percentage)
Biosolids technology	AD biogas with cogeneration engines	11-61
	AD biogas after WAS pretreatment	~2-60
	AD biogas with co-digestion	2-128
	Incineration	2-69
	Gasification	~9-82
Other technology	Enhanced solids removal	10-71
	Anaerobic primary treatment	25-139
	Microbial fuel cells	8-110
	Biofuel from algae	~39-208
	Enhanced solids removal	10-71

Source: Deines, 2013.

Net energy: the energy to be extracted from the incoming wastewater for facility primary energy self-sufficiency (i.e., the "Gap" ≈1.9-7.2 MJ/m^3).

Wastewater treatment plants (WWTPs)

Energy conservation measures

Energy conservation measure	Treatment stage	Energy savings range (%)
Wastewater pumping optimization	Throughout system	<0.7
Aeration system optimization	Secondary treatment	~15-38
Addition of pre-anoxic zone for BNR	Secondary treatment	~4-15
Flexible sequencing of aeration basins	Secondary treatment	~8-22
High-efficiency UV	Disinfection	~4
Lighting system improvements	Support facilities (buildings)	~2-6

Source: Deines, 2013.

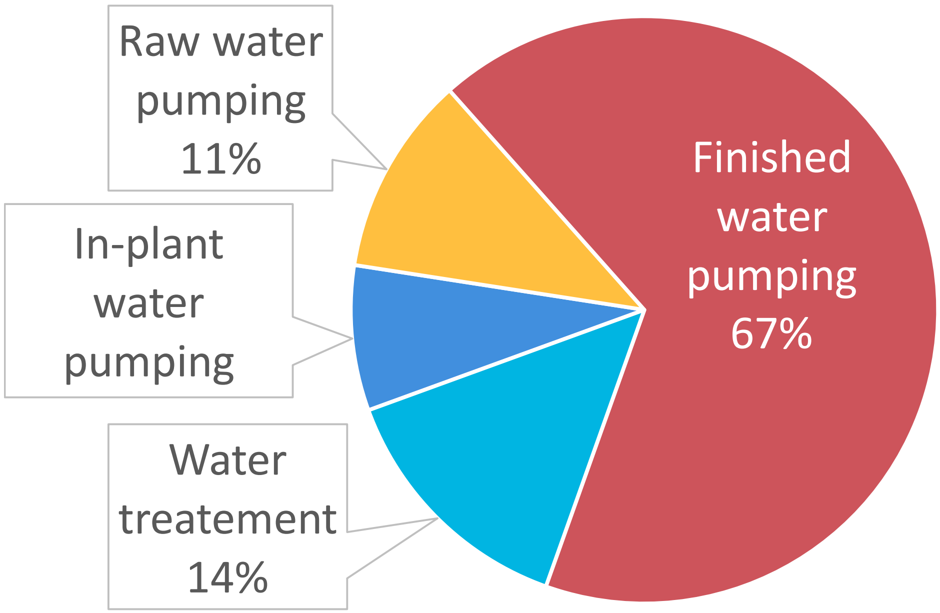
Energy intensity of recycled water treatment and end uses of the recycled water

Technologies Used	Energy Use (kWh/MG)	End Use
Conventional Tertiary Treatment		
Flocculation, direct filtration, UV/advanced oxidation	1,500	Irrigation, industrial use
Clarification, media filtration, chlorination	1,619	Irrigation, industrial and commercial use
Anthracite coal bed filtration, UV	1,703	Irrigation, industrial use
Rapid mix, flocculation, media filtration, UV	1,800	Irrigation
Membrane Treatment		
MF, RO, UV/advanced oxidation	3,680	Groundwater recharge
UF, RO, UV	4,050	Industrial use
MF, RO	4,674	Industrial use
MF, RO	8,300	High-quality industrial use

Source: Water in the West, 2013.

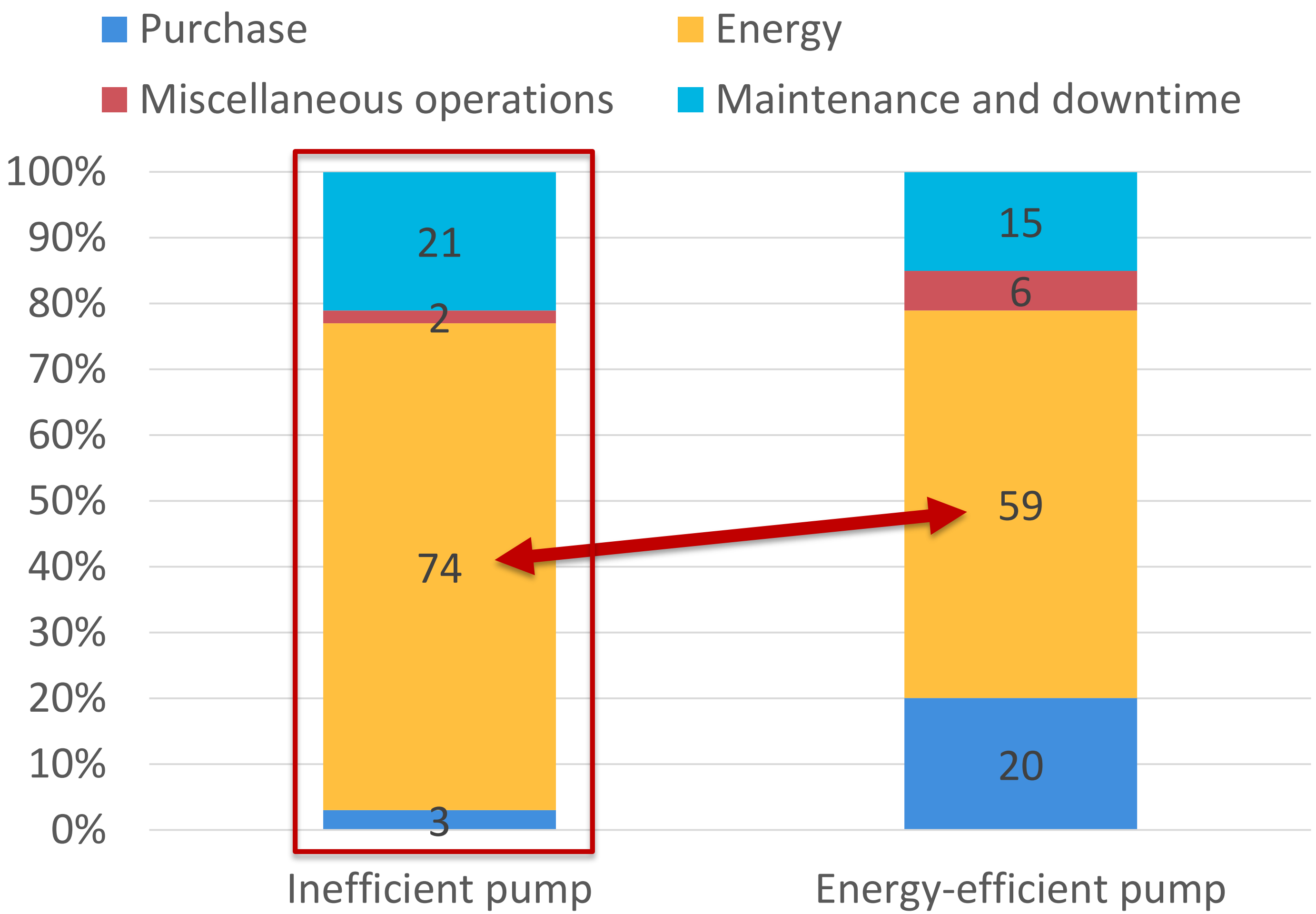
Energy efficiency in water distribution systems

Typical energy end-uses in a public surface water system



Source: Reekie, 2013.

Life cycle costs of inefficient vs. efficient pump systems (percentage)

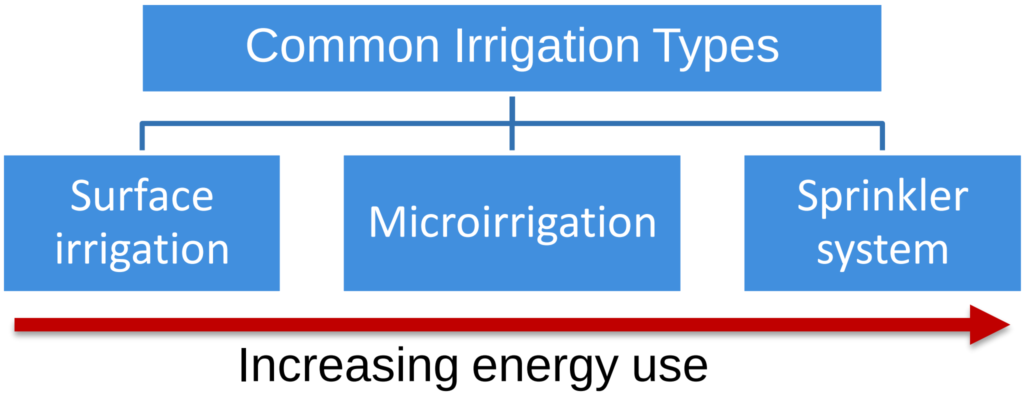


Inefficient pump
Purchase price: US$28,000
1st year energy cost: US$69,000
Total in first year: US$97,000

Energy-efficient pump
Purchase price: US$56,000
1st year energy cost: US$19,600
Total in first year: US$75,600

Source: Reekie, 2013.

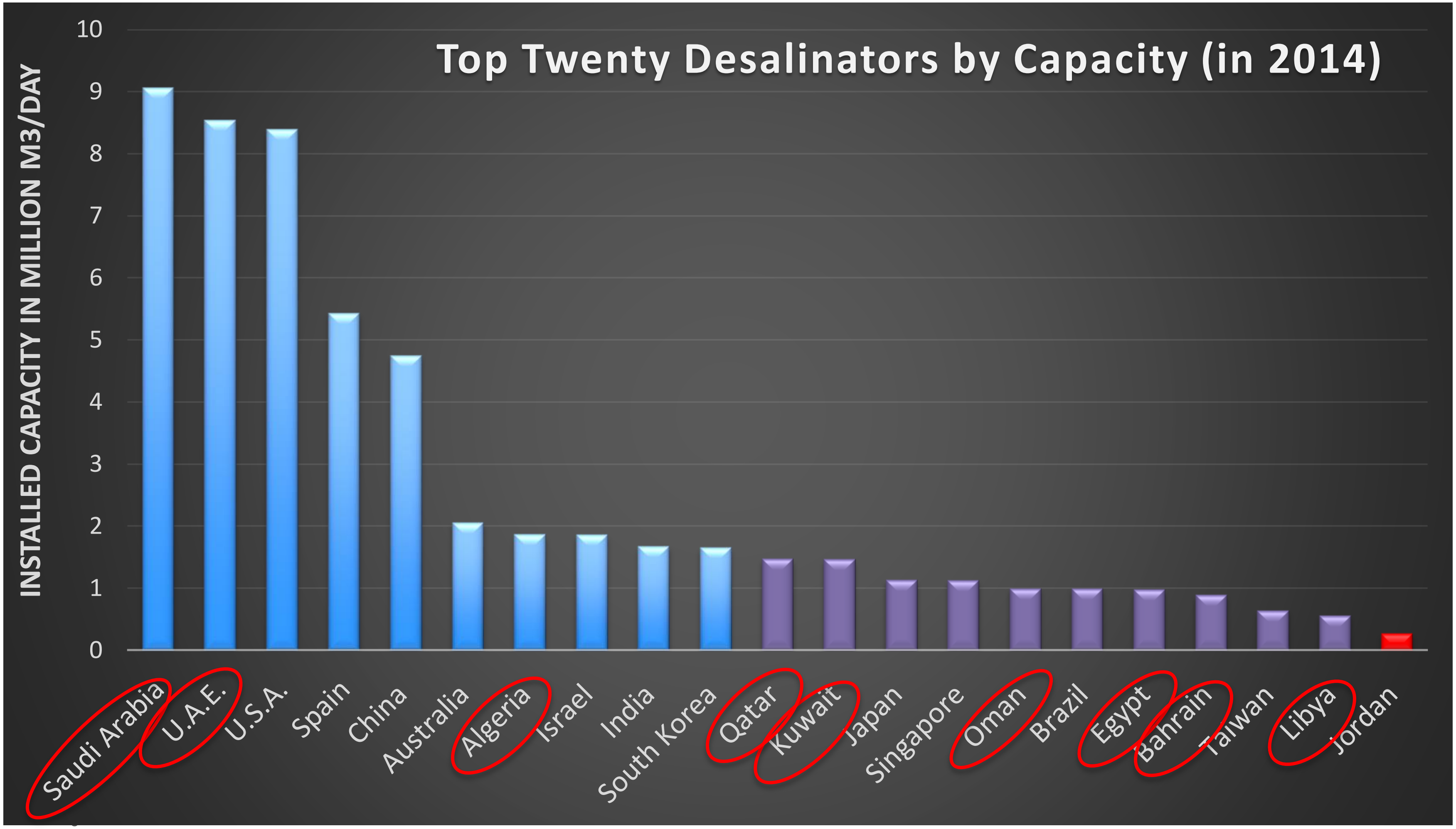
Energy efficiency in water distribution systems



- Energy efficiency can be improved in water supply systems by:
  - Upgrading the design of pump stations
  - Increasing tank capacity
  - Installing variable speed drives (VSDs) for the pumps.
  - Installing pressure-reducing valves along the pipes network.

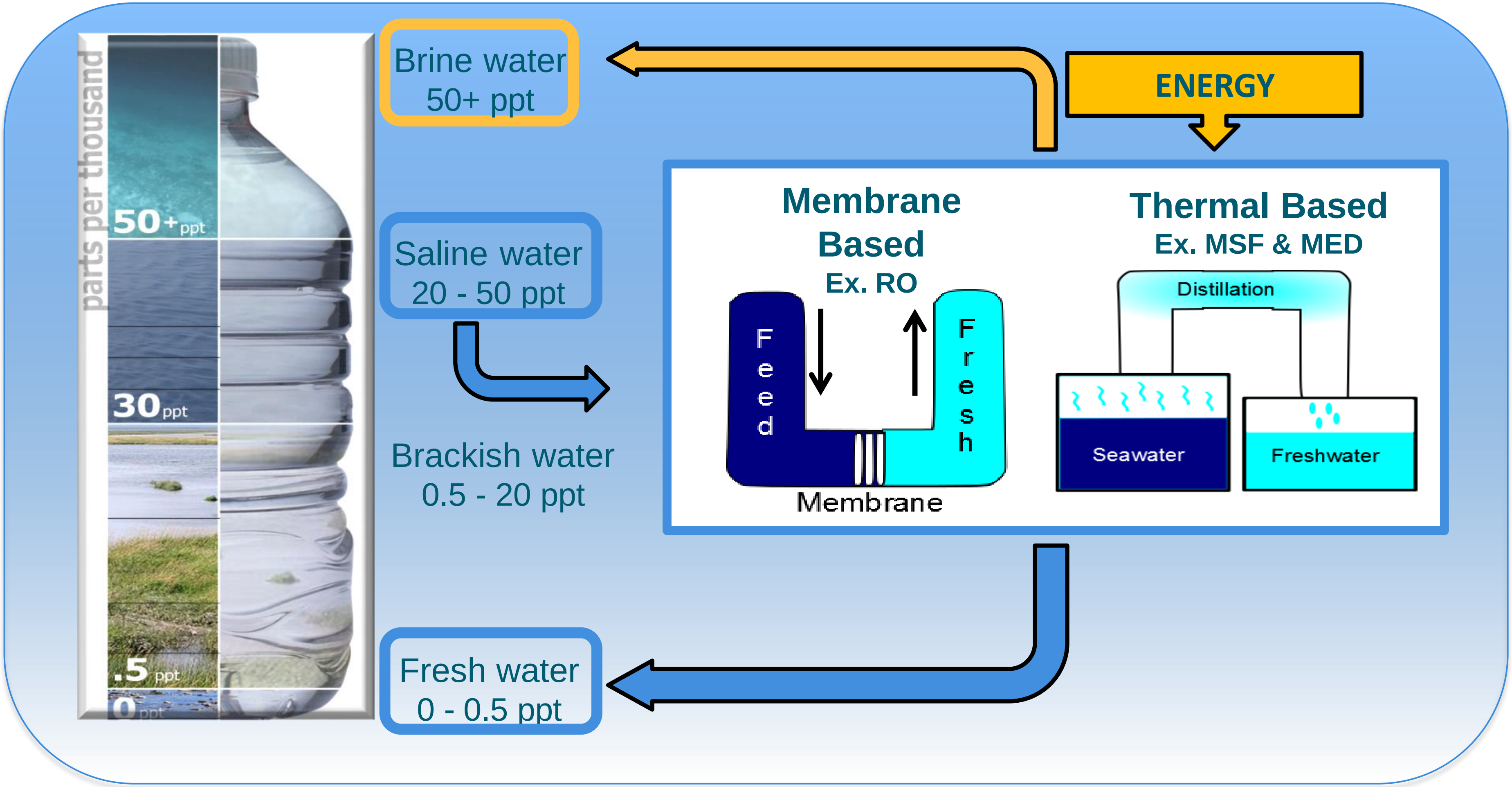
Energy efficiency in desalination

Global installed desalination capacity



Source: DesalData.com, 2014.

The desalination process



Energy use in seawater desalination

From thermal to membrane processes

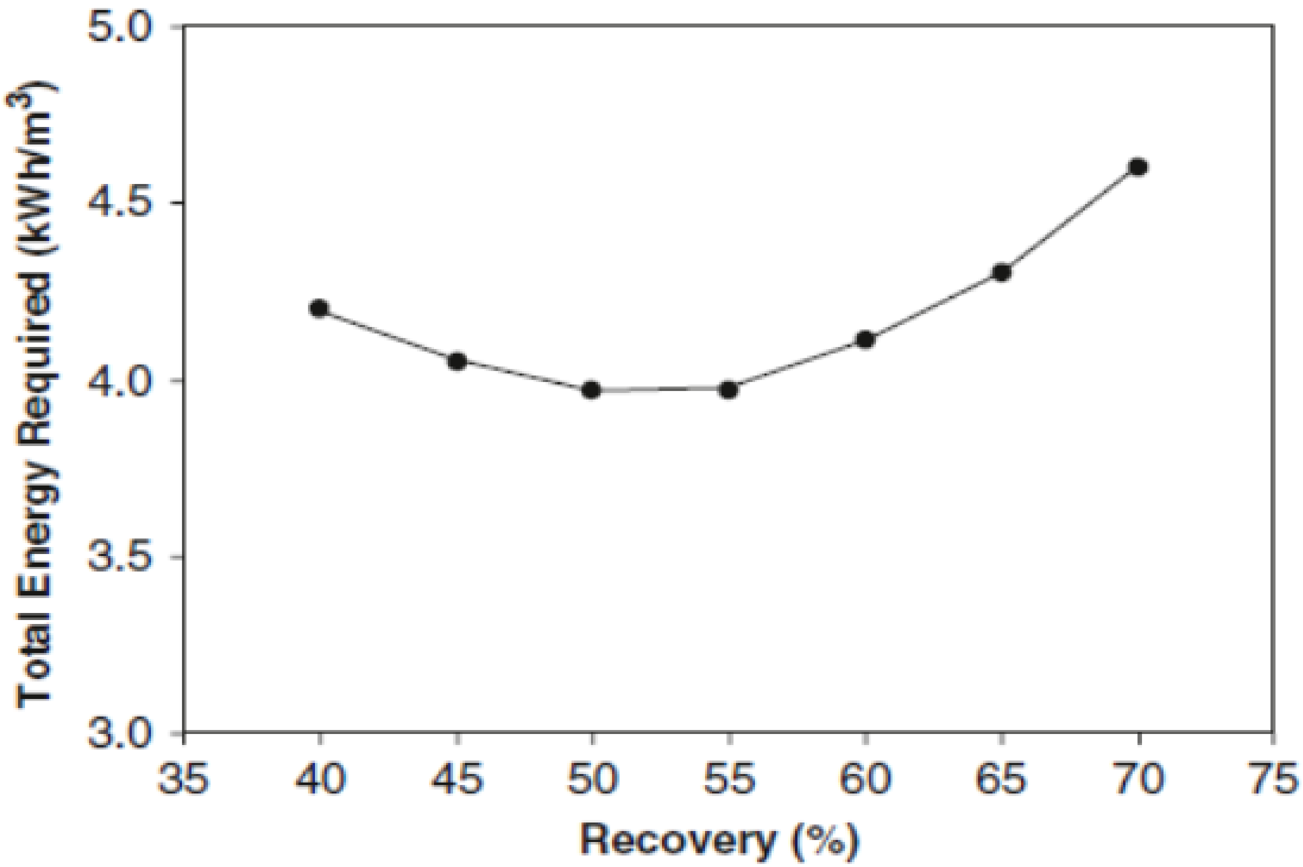
	Equivalent electrical energy required (kWh/m^3)
Multistage Flash (MSF)	25
MSF coproduction	14
MED-TVC coproduction	11
Reverse osmosis (Mediterranean)	3.5
Ideal reversible desalination	0.8 to 2
Water recycling – MBR*	0.5 to 1.5
Distributing water (150 km, no grade)	0.6

Decreasing energy use

* Representative wastewater recycling by membrane bioreactor, low value nonpotable.

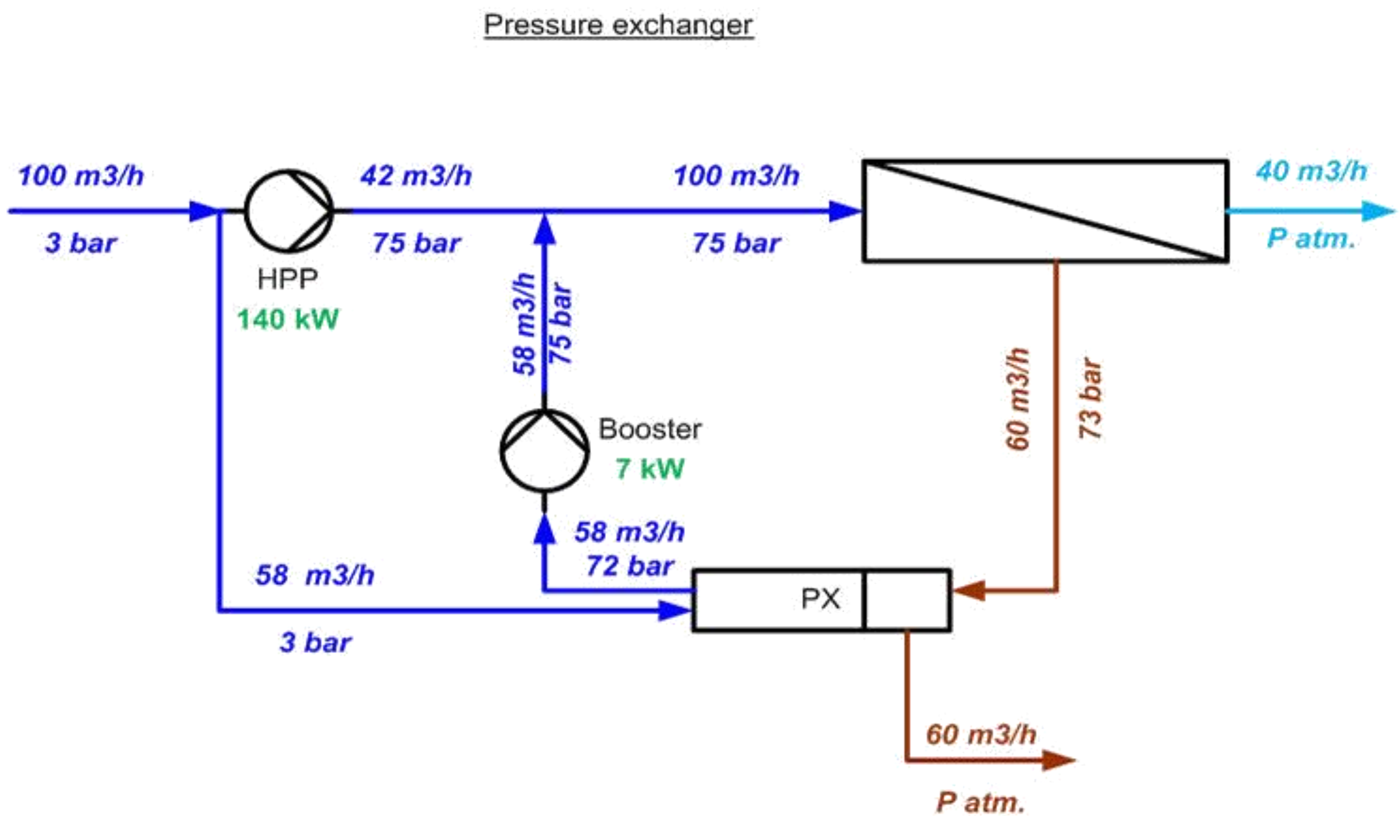
Source: Sommariva, *Desalination and Advanced Wastewater Treatment Economics*, Balaban Pub., 2010

Total energy required per volume of permeate as a function of the RO system recovery



Source: Ray & Jain, 2011.

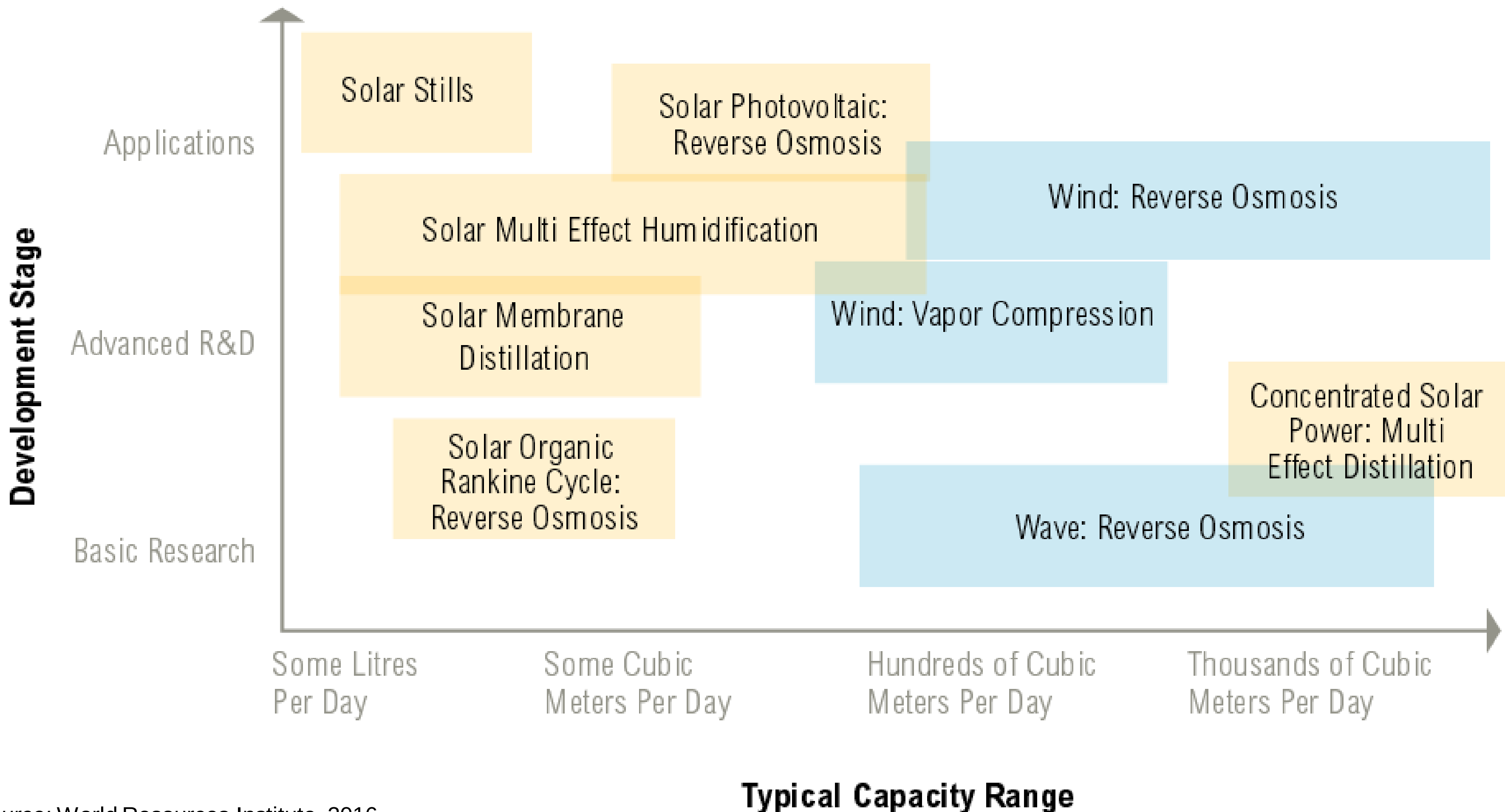
Improving RO system energy efficiencies



Powering desalination with Renewable Energy

- Desalination powered by renewable energy (RE) will continue to increase in importance in the Arab countries.
- RE-powered desalination already best alternative for stand-alone power-generating systems in remote regions.
- Solar, wind and geothermal energy can be used to power desalination.
- The energy efficiency of desalination processes does not tend to vary greatly according to the energy source used.
- Challenges of RE technology: high capital costs and intermittence.
- Renewable energy potential at a particular location must be considered as part of designing such desalination plants.

RE-desalination: Maturity



Source: World Resources Institute, 2016.

Key messages

- The most energy-consuming parts of a process must be targeted.
  - For wastewater treatment this is aeration.
  - For water distribution systems this is pumping.
- More energy-efficient desalination technologies can play a pivotal role in improving the overall energy consumption of the region.
  - RO is currently the technology of choice but there is still room for improvement.
  - The use RE to power desalination is rapidly being adopted in the region.
- Intelligent systems have the potential to increase efficiencies.
  - They help match supply and demand.
  - They can have low capital costs.
- Energy efficiency measures which require the least effort can be very beneficial.

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THANK YOU