RENEWABLE ENERGY IN DESALINATION AND ELECTRICITY PRODUCTION

Water-Energy Nexus Operational Toolkit : Renewable Energy

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Economic and Social Commission for Western Asia

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Outline

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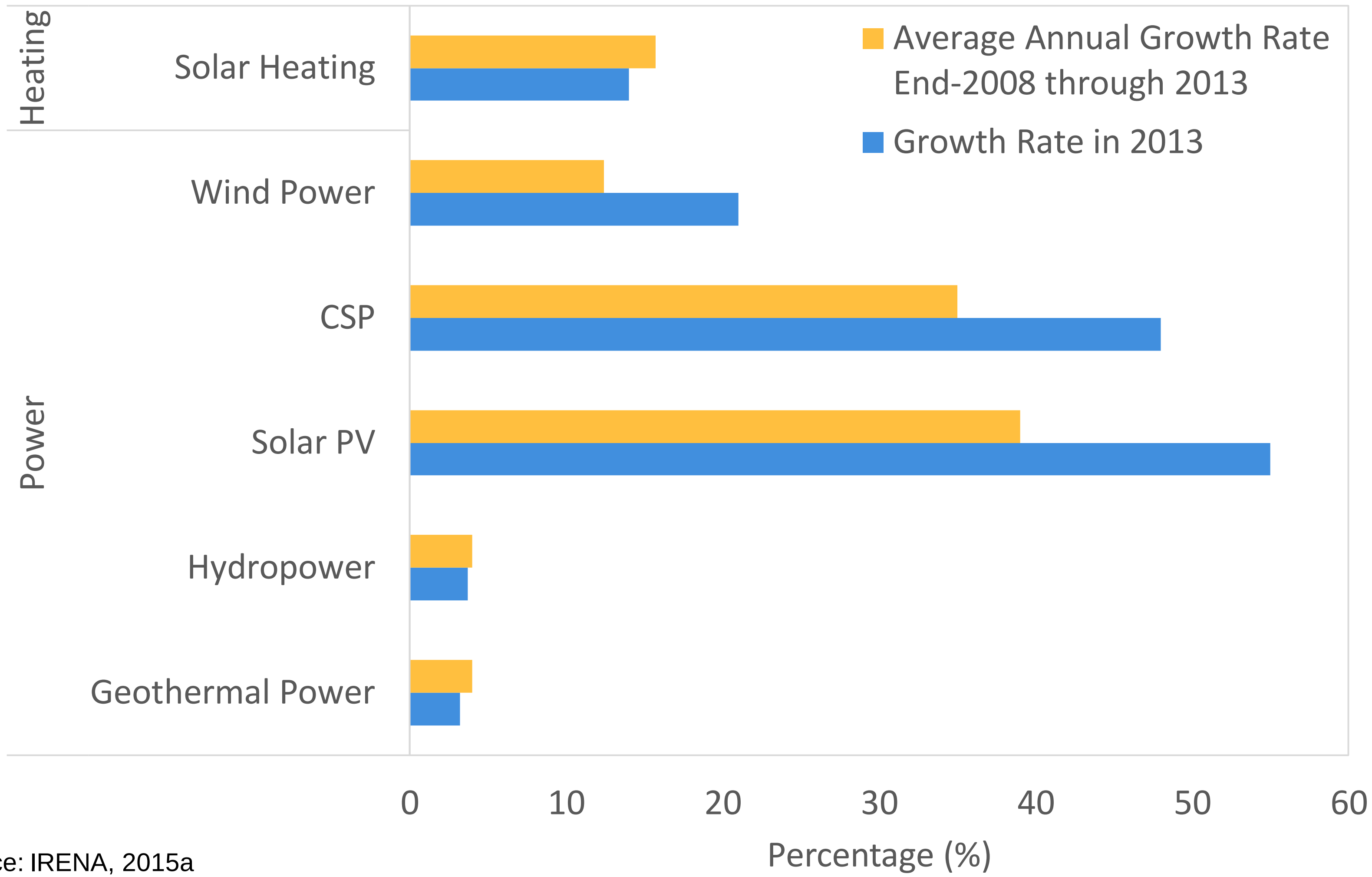
Introduction

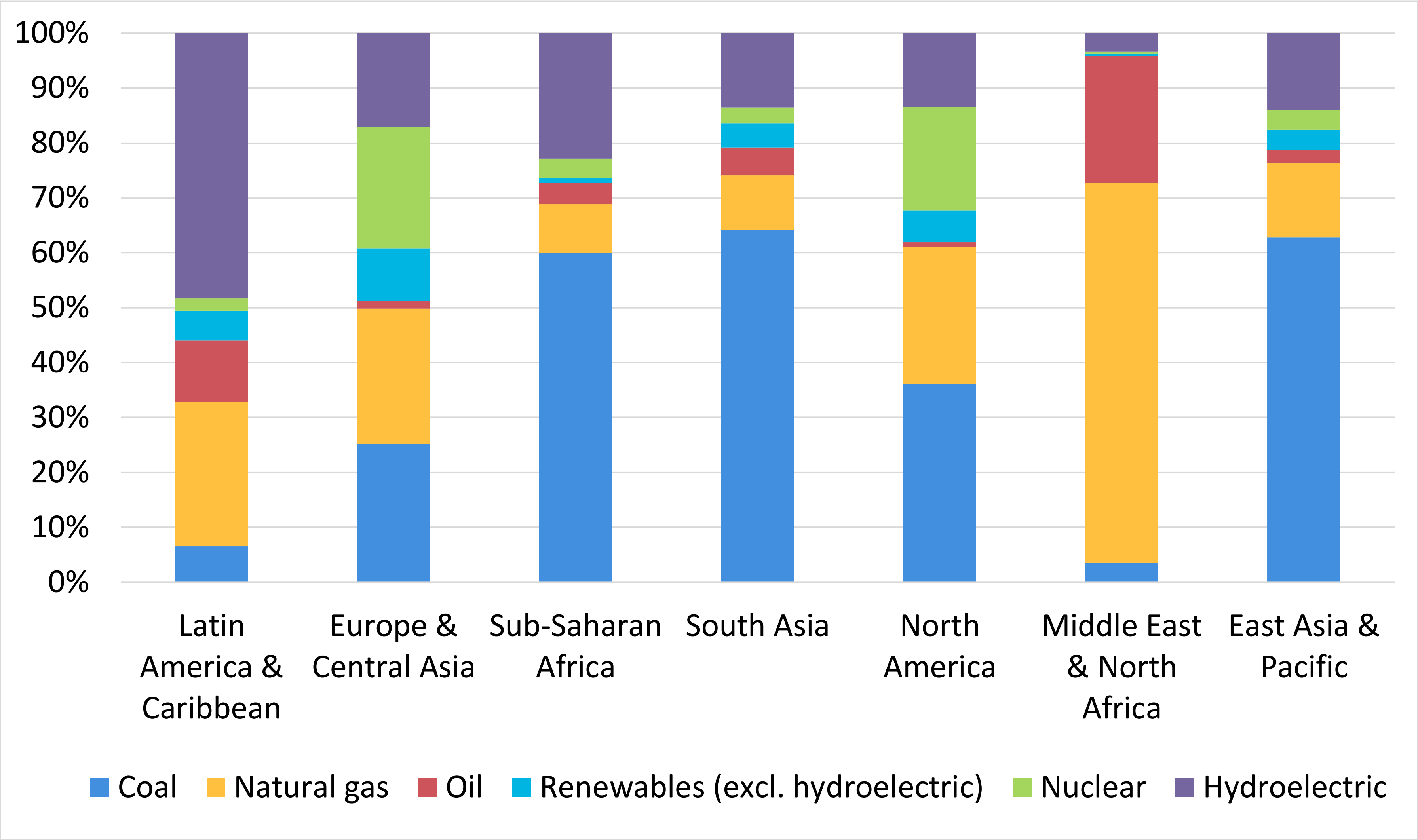
Average annual global growth in RE capacity by sector



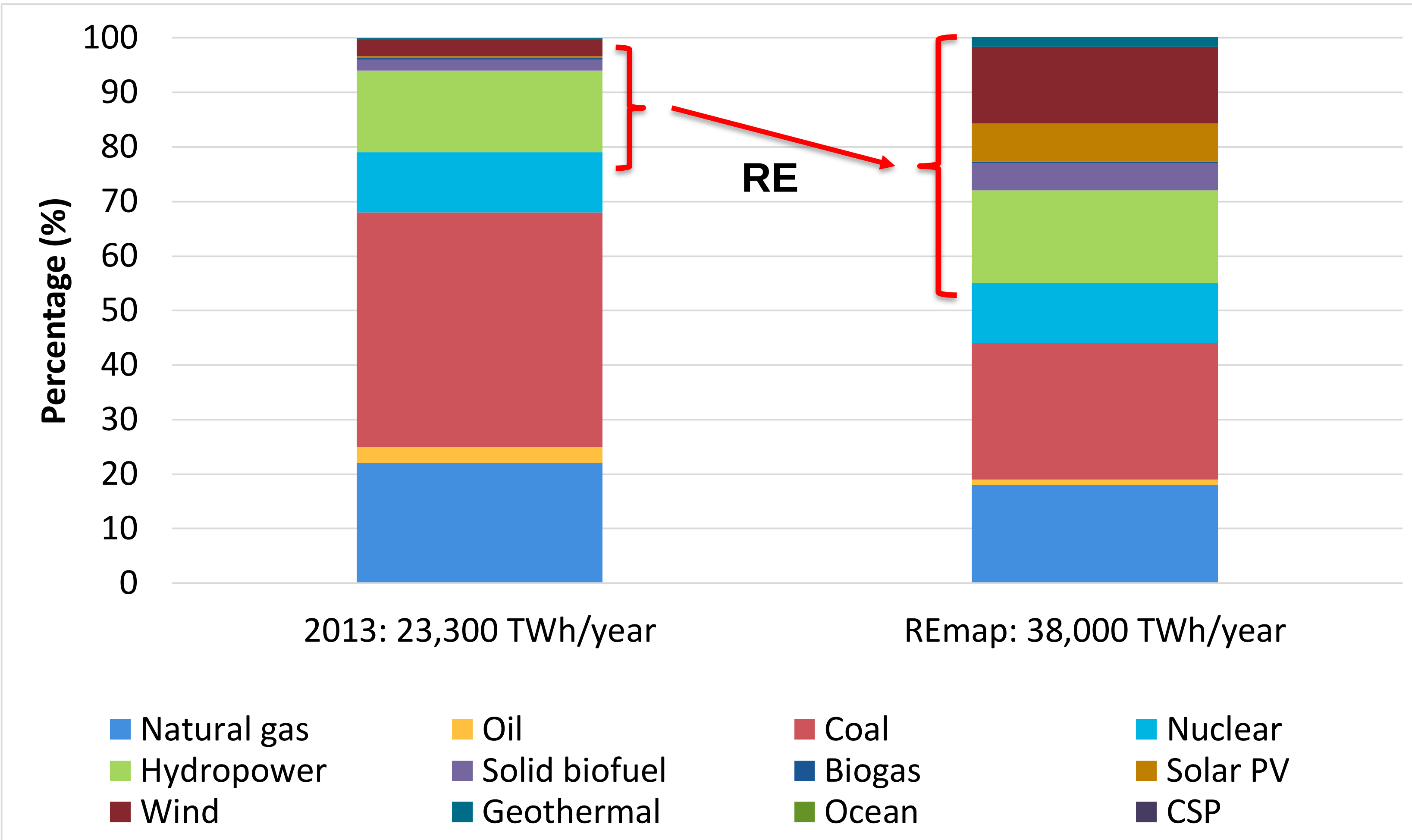
Source: IRENA, 2015a

Share of fuel types in total electricity generation by world region (2013)

Source: The World Bank, 2015.



Global power generation: 2013 vs. 2030



Source: IRENA, 2016a

RE Projects in the Arab Countries: Planned/Under Construction

Wind PV CSP Geothermal

Algeria	MW
Khenchela	20
Distributed projects at different sites	73
Guelma	5
North and Upper Platheus	343
North and Upper Platheus	5010

Egypt	MW
Gabal El-Zayt	220
Gulf of El-Zayt	120
FiT wind projects	2000
FiT PV projects	2300

Jordan	MW
Maan	75
Shamsuna Aqaba	10
Al Quaira / Al Aqaba	150
Al Mafraq	10
NEPCO/Masdar	200
Additional projects	400
Additional projects	230
Al Fagig / Al Shobk	90

Kuwait	MW
Shagaya RE Complex I	10
Shagaya RE Complex I	10
Shagaya RE Complex I	10

Lebanon	MW
Systems under the National Energy Efficiency and Renewable Energy Action (NEEREA)	30
To be confirmed, under bidding process	60-100

Libya	MW
Darnah	60
Al-Magron I	80
Al-Magron I	120
Al-Jofra	14
Houn	14
Sebha	40

Morocco	MW
Taza	150
Tanger II	100
Jbel Khalladi	120
Boujdour	100
Tiskrad	300
Midelt	150
Jbel Lahdid	200
Noor II	200
Noor III	150

Djibouti	MW
Grand Bara	300

Mauritania	MW
Nouakchott	30
Nouakchott	30

Oman	MW
Amal Oil Field	1021
Dhofar Wind Farm	50

State of Palestine	kW
Tubas	470
Jericho	700

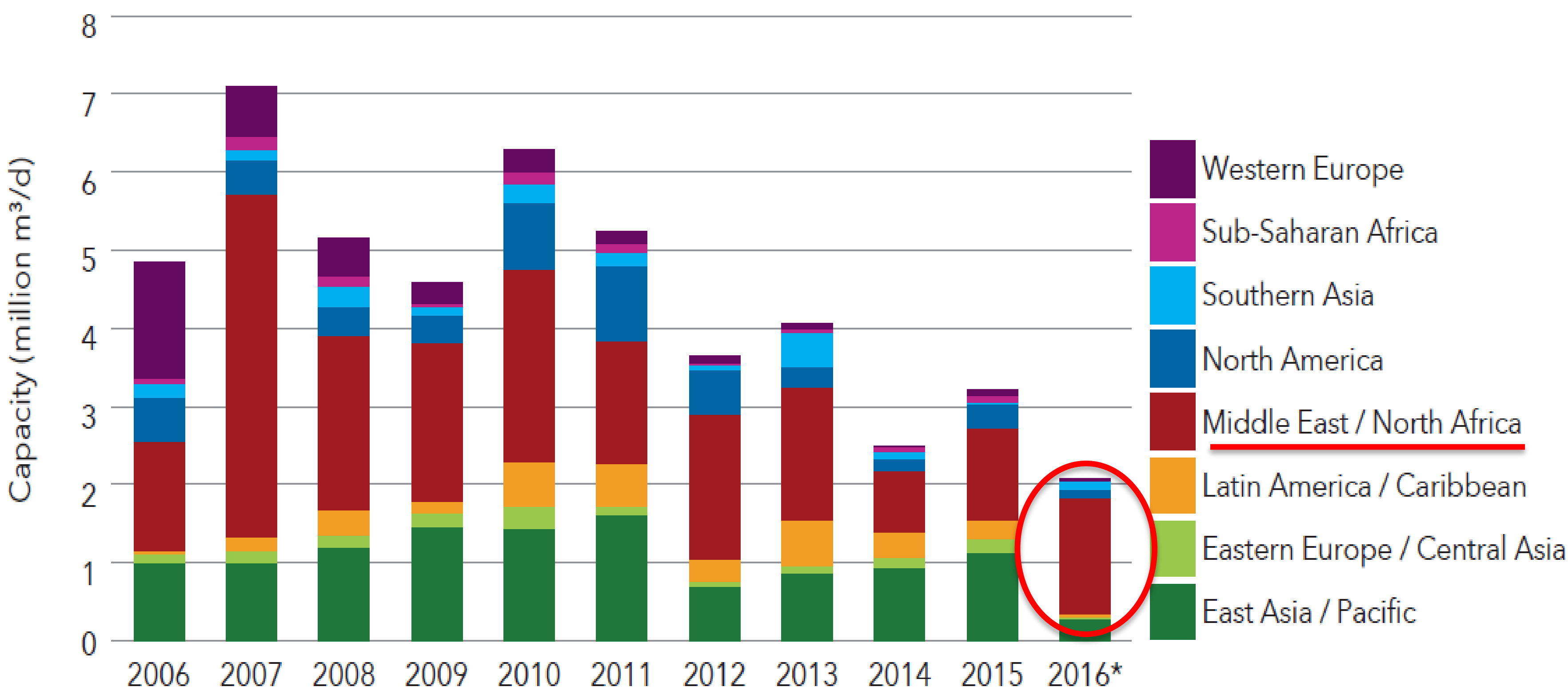
Qatar	MW
Duhail	10
Kahramaa project	100

Saudi Arabia	MW
Al Khafji	15
Mecca	100
Green Duba ISCC	50

UAE	MW
Dubai MBR Solar Park Phase 2	470
Abu Dhabi Solar Park (including Noor 1 project)	700

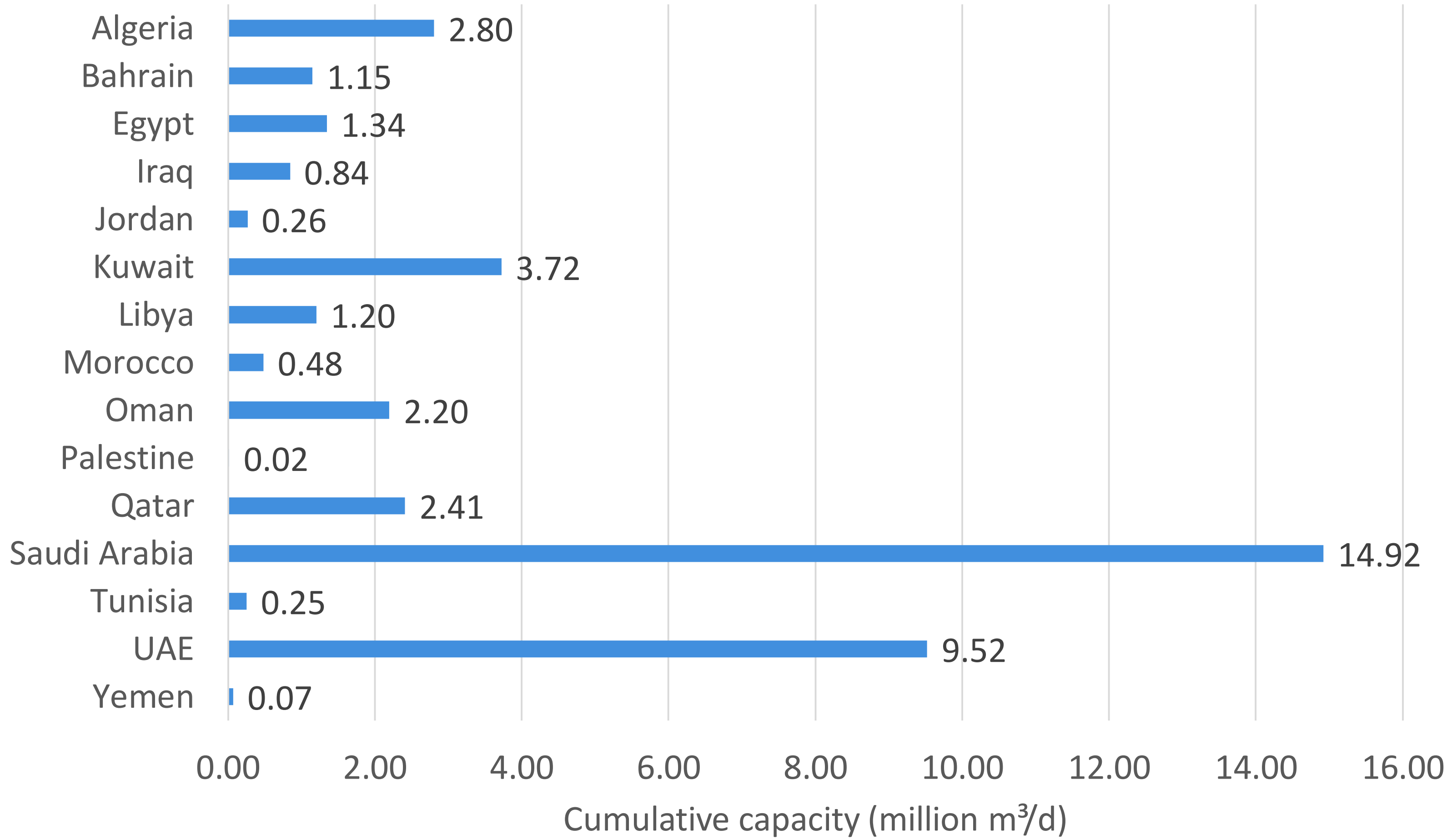
Source: IRENA, 2016b

Annual contracted desalination capacity by region



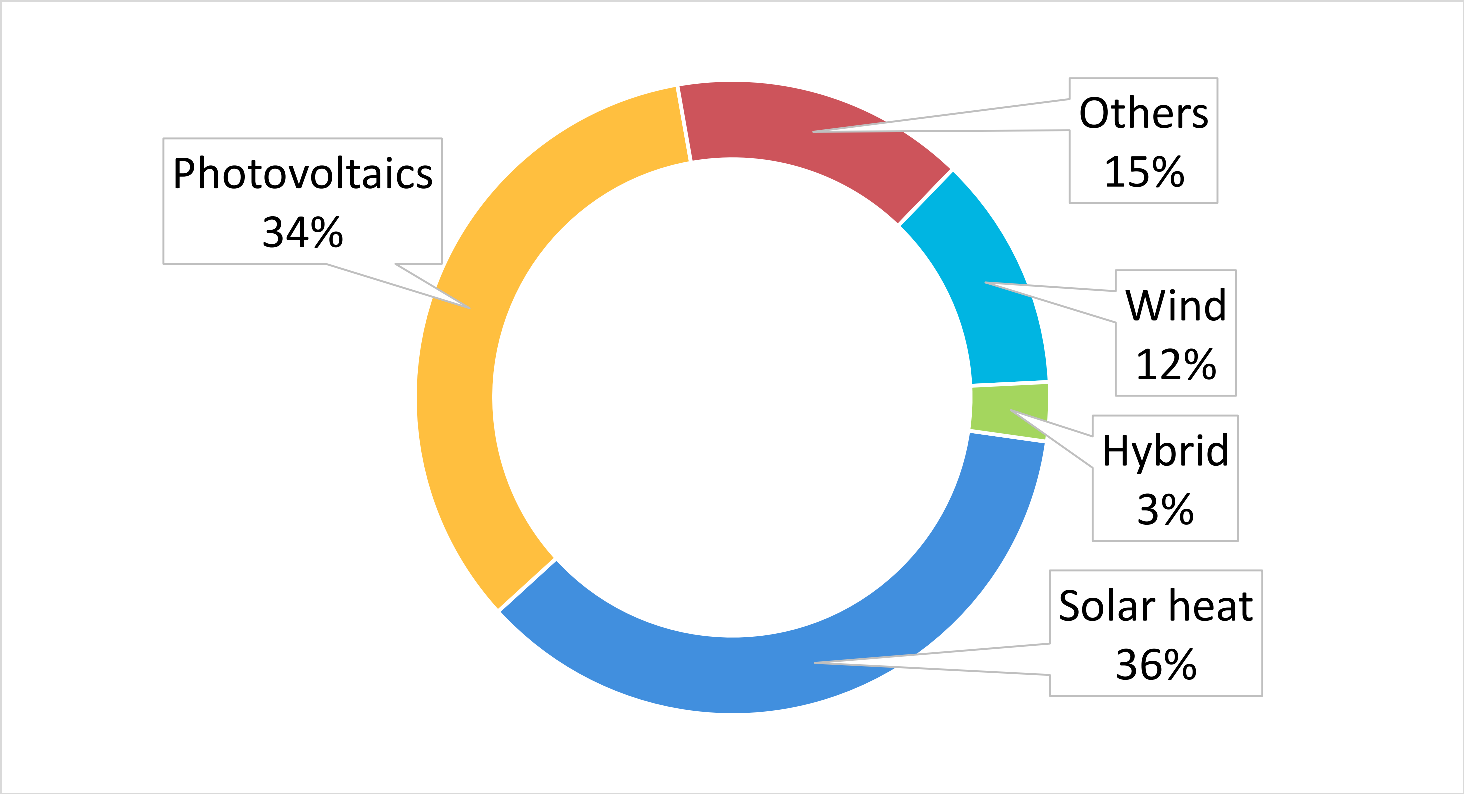
Note: *values through June 2016;
Source: Virgili et al., 2016.

Cumulative contracted desalination capacity in 2015 by country



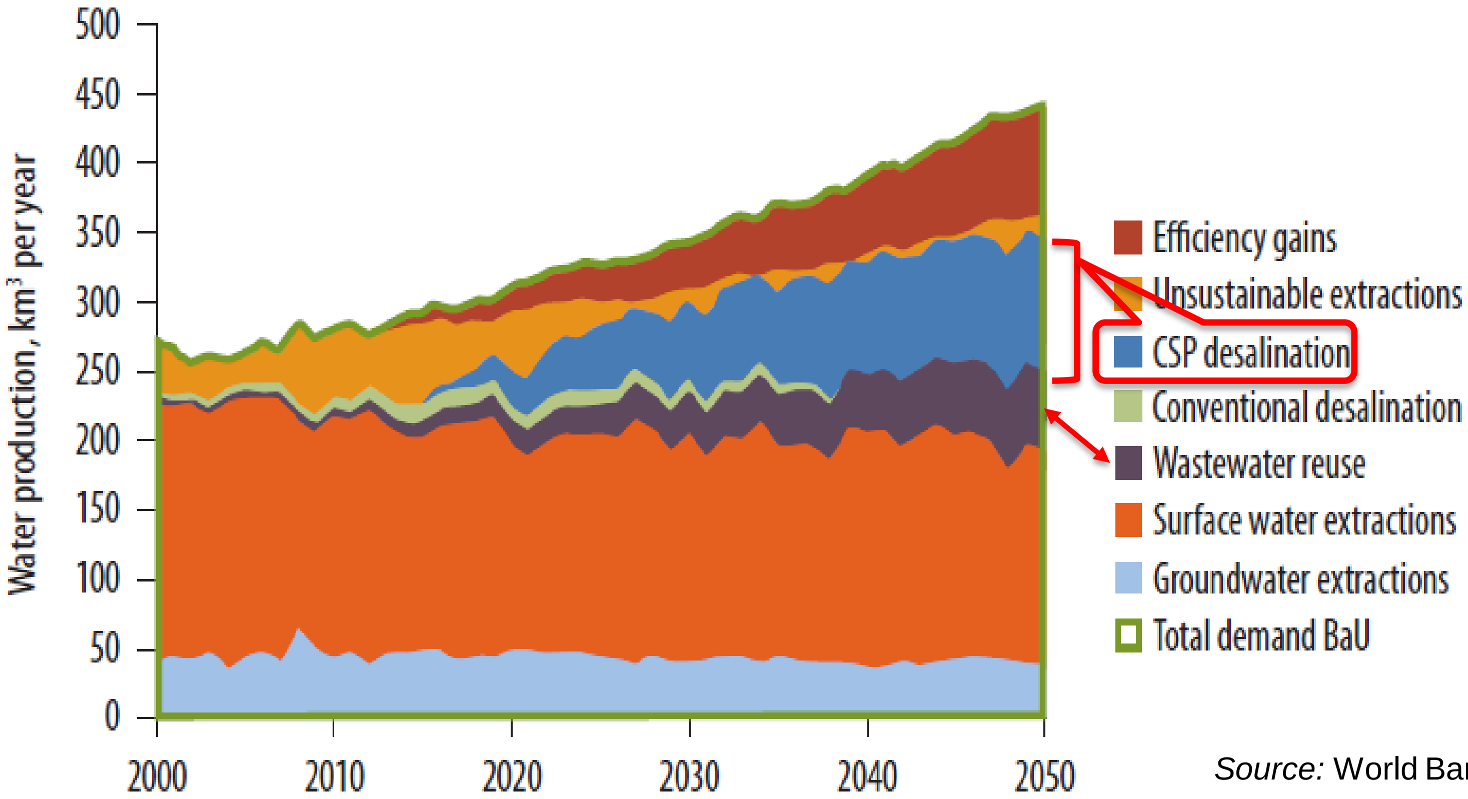
Source: Alvarado-Revilla, 2015.

Global RE desalination by energy source in 2009



Source: World Bank, 2012.

Future water supply for the MENA region under the Business as Usual (BaU) Scenario



Source: World Bank, 2012.

The CSP potential of the MENA region estimated to be 462,000 TWh annually; ~350 times greater than the region's annual energy consumption (as of 2012).

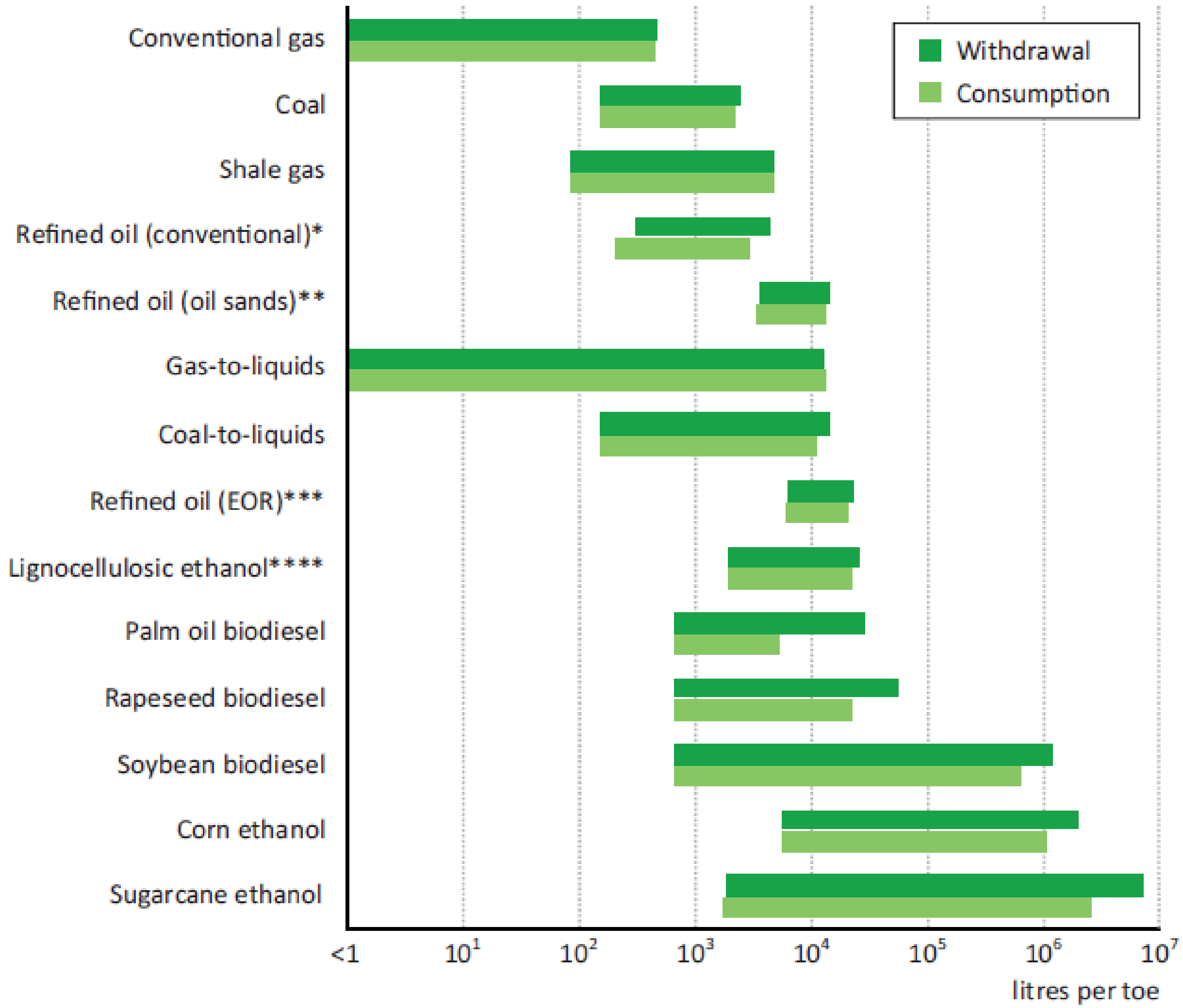
Electricity Production

Key uses of water for energy and potential water quality impacts

	Uses	Potential water quality impacts
Primary energy production		
Biofuels	• Irrigation for feedstock crop growth. • Wet milling, washing and cooling in the fuel conversion process.	• Contamination by runoff containing fertilisers, pesticides and sediments (surface and groundwater). • Wastewater produced by refining.
Power generation		
Thermal (fossil fuel, nuclear and bioenergy)	• Boiler feed, i.e. the water used to generate steam or hot water. • Cooling for steam-condensing. • Pollutant scrubbing using emissions-control equipment.	• Thermal pollution by cooling water discharge. • Impact on aquatic ecosystems. • Air emissions that pollute water downwind. • Discharge of boiler blowdown, i.e. boiler feed that contains suspended solids.
CSP and geothermal	• System fluids or boiler feed, i.e. the water used to generate steam or hot water. • Cooling for steam-condensing.	• Thermal pollution by cooling water discharge. • Impact on aquatic ecosystems.
Hydropower	• Electricity generation. • Storage in a reservoir (for operating hydro-electric dams or energy storage).	• Alteration of water temperatures, flow volume/timing and aquatic ecosystems. • Evaporative losses from the reservoir.

Source: International Energy Agency, 2012.

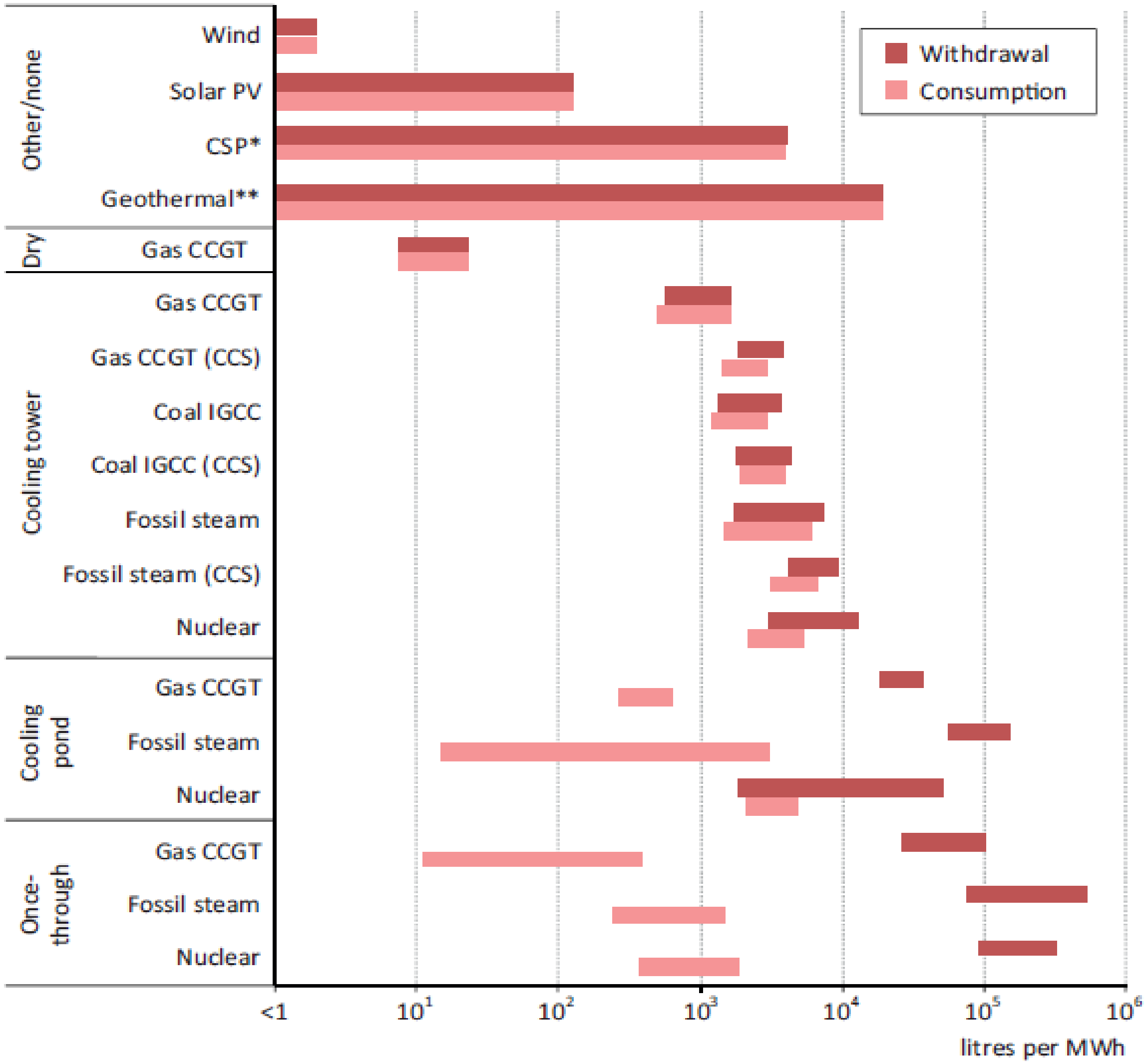
Water use for primary energy production



Source: International Energy Agency, 2012.

Electricity production

Water use for electricity generation by cooling technology



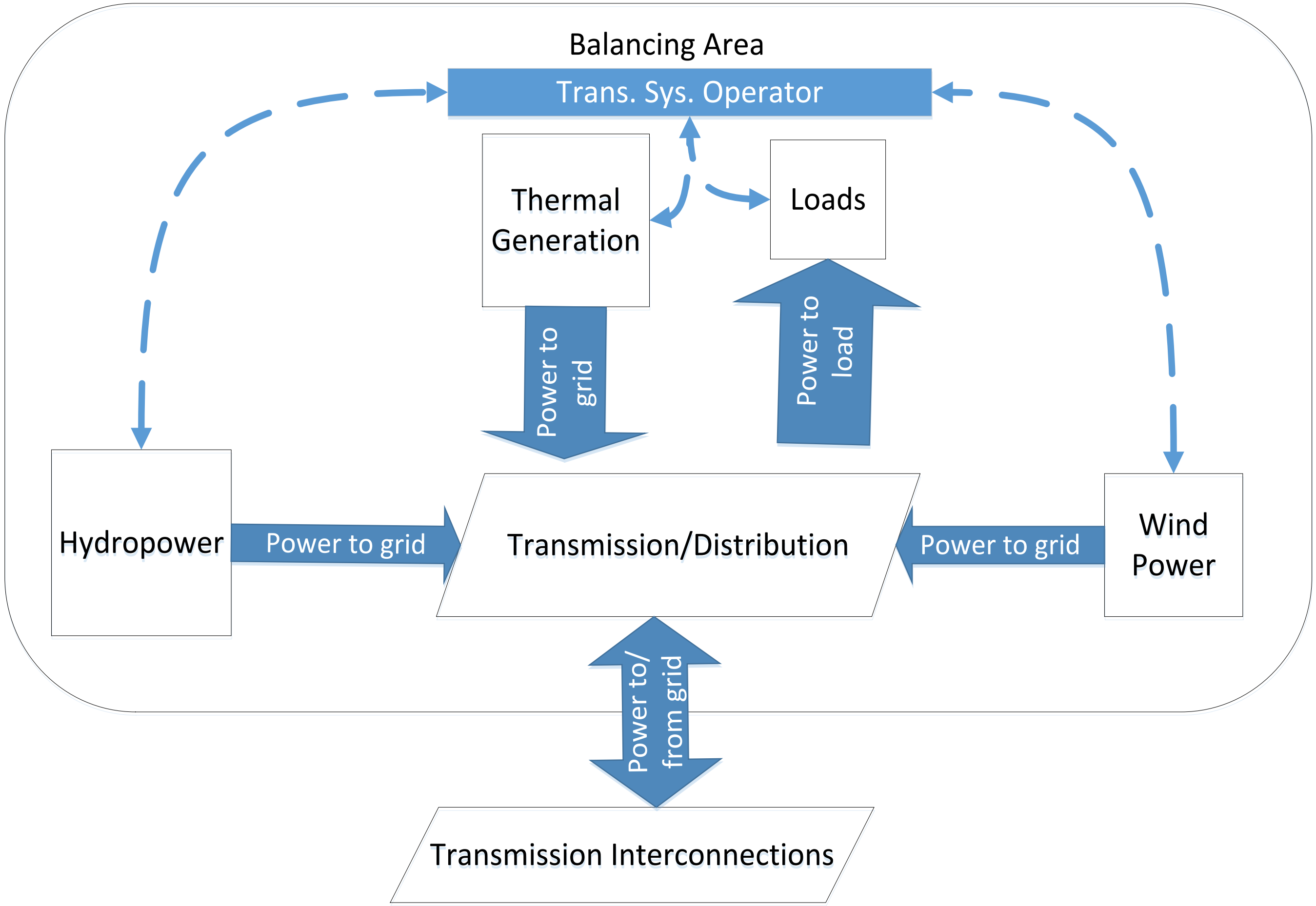
Source: International Energy Agency, 2012.

Microhydropower systems

- Hydropower systems which generate up to 100 kW of electricity and a minimum head of 3 ft and water flow ≈ 20 gallons/minute is required.
- A portion of water is diverted from the water source and is directed into a structure such as a channel or a pressurized pipeline which delivers it to the (usually impulse) turbine or waterwheel.
- Can be off-grid or grid-connected and used in areas such as large homes, small businesses and can be integrated into water supply networks and wastewater infrastructure.
- Not intermittent unlike other RE sources and less costly than wind or solar energy, particularly in terms of capital costs.

Electricity production

Configuration for the integration of wind and hydropower resources



Source: Acker, 2011.

Desalination

RE desalination in the Arab countries – Status quo

- Existing renewable desalination systems have small capacities (up to 100 m3/d).
- Only a small number of medium-sized installations are in use.
- Mainly pilot size plants operational in Egypt, Jordan, Morocco, and the UAE.
- Largest PV desalination plant in Khafji, Saudi Arabia with capacity of 60,000 m3/d and using nanomembranes to be commissioned in 2017.

Characteristics of different desalination processes

Source: Gude et al., 2010.

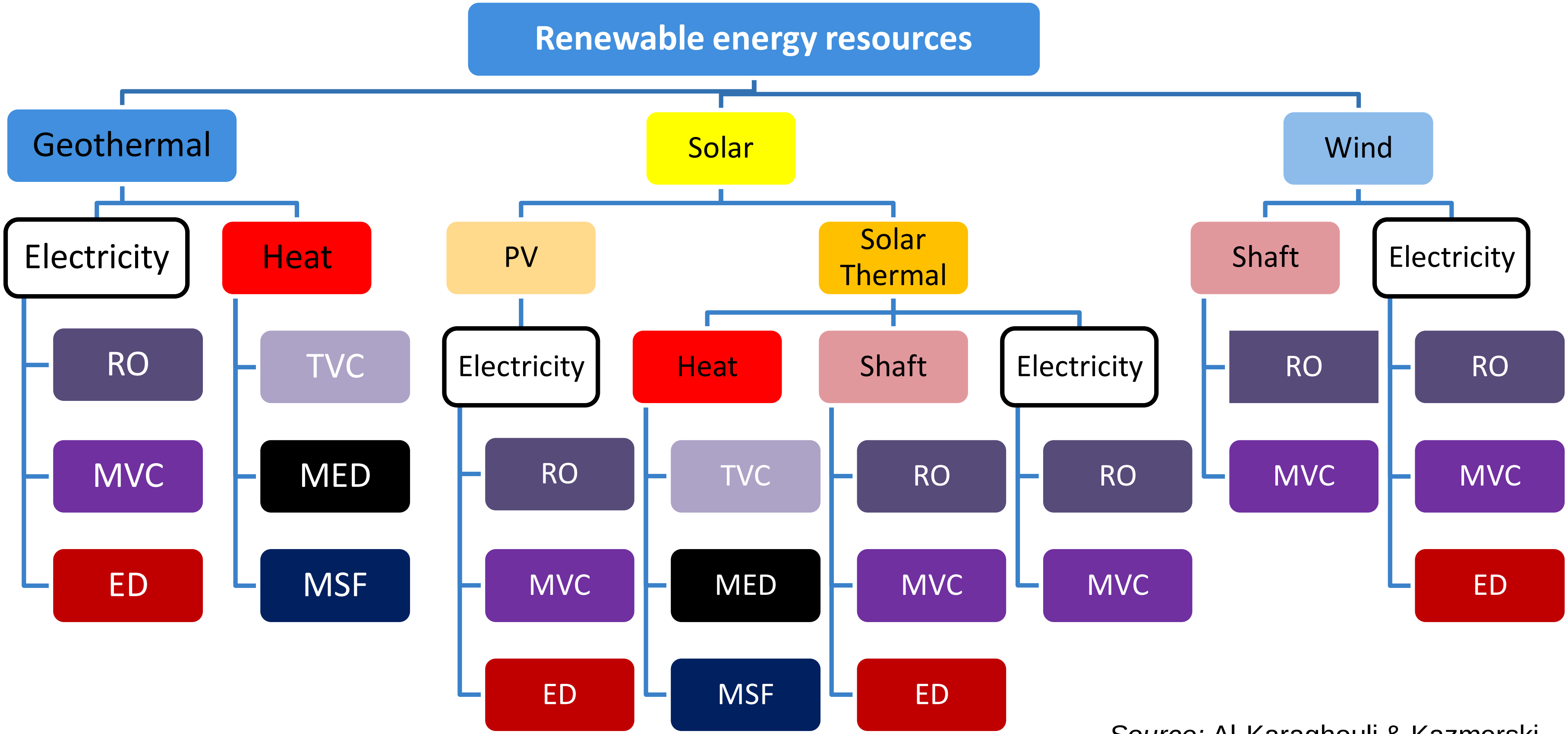
Characteristic	Type of process		
	Phase change	Non-phase change	Hybrid
Process nature	Thermally-driven process: MED, MSF, MVC, TVC (evaporation and condensation)	Pressure/concentration gradient driven: RO (membrane separation), ED (electrochemical separation)	Thermal + membrane: membrane distillation, MSF/RO, MED/RO
Membrane pore size	-	0.1–3.5nm	0.2–0.6µm
Feed temperature	60–120ºC	<45ºC	40–80ºC
Cold water stream	May be required	-	20–25ºC
Driving force for separation	Temperature and concentration gradient	Concentration and pressure gradient	Temperature and concentration gradient
Energy	Thermal and mechanical	Mechanical and/or electrical	Thermal and mechanical
Form of energy	Steam, low-grade heat or waste heat and some mechanical energy for pumping derived from fossil fuels or renewable sources	Requires prime quality mechanical/ electrical energy derived from fossil fuels or renewable sources	Low-grade heat sources or RE sources
Product quality	High quality distillate with TDS <20ppm	Potable water quality TDS <500ppm	High quality distillate with TDS 20–500ppm

Seawater characteristics variation in the Arab region

Water source	Salinity (mg/L)	Temperature (°C)
Mediterranean and Atlantic	38,000–41,000	15–30
Red Sea and Indian Ocean	41,000–43,000	20–35
Gulf water	45,000–47,000	20–35

Source: World Bank, 2012.

Pathways for RE integration with desalination technologies



Source: Al-Karaghouli & Kazmerski, 2011; IRENA, 2015a.

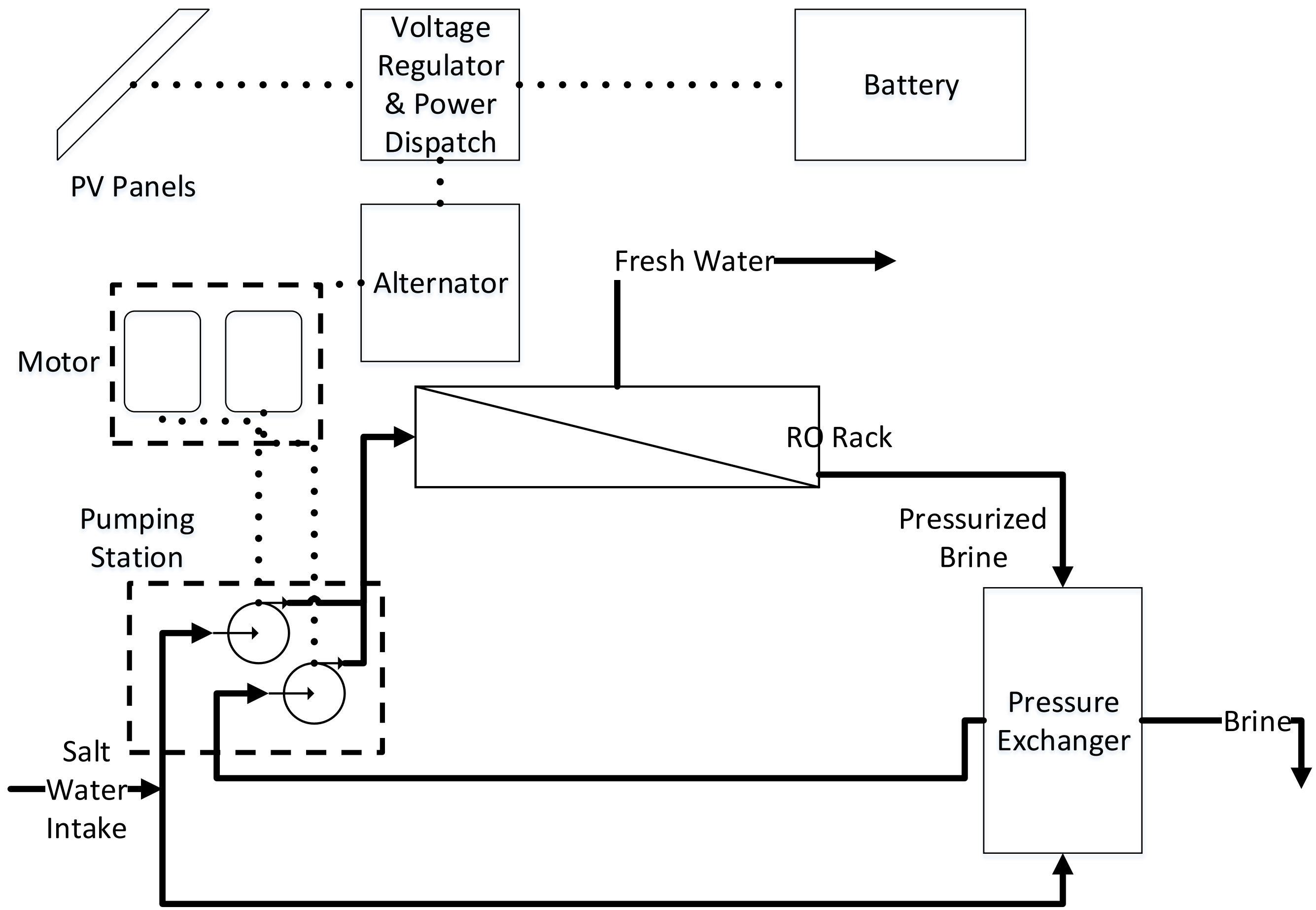
Pathways for RE integration with desalination technologies

	Technical Capacity (m^3/d)	Energy Demand (kWh/m^3)	Development Stage
Solar stills	< 0.1	Solar passive	Application
Solar-Multiple Effect Humidification	1-100	thermal: 100 electrical: 1.5	R&D; Application
Solar- MD	0.15-10	thermal: 150–200	R&D
Solar/CSP-MED	> 5,000	thermal: 60–70 electrical: 1.5–2	R&D
PV-RO	< 100	electrical: BW: 0.5–1.5; SW: 4-5	R&D; Application
PV - Electrodialysis Reversed	< 100	electrical: only BW:3–4	R&D
Wind- RO	50-2,000	electrical: BW: 0.5–1.5; SW: 4–5	R&D; Application
Wind- MVC	< 100	electrical: only SW:11–14	Basic Research

Solar desalination systems

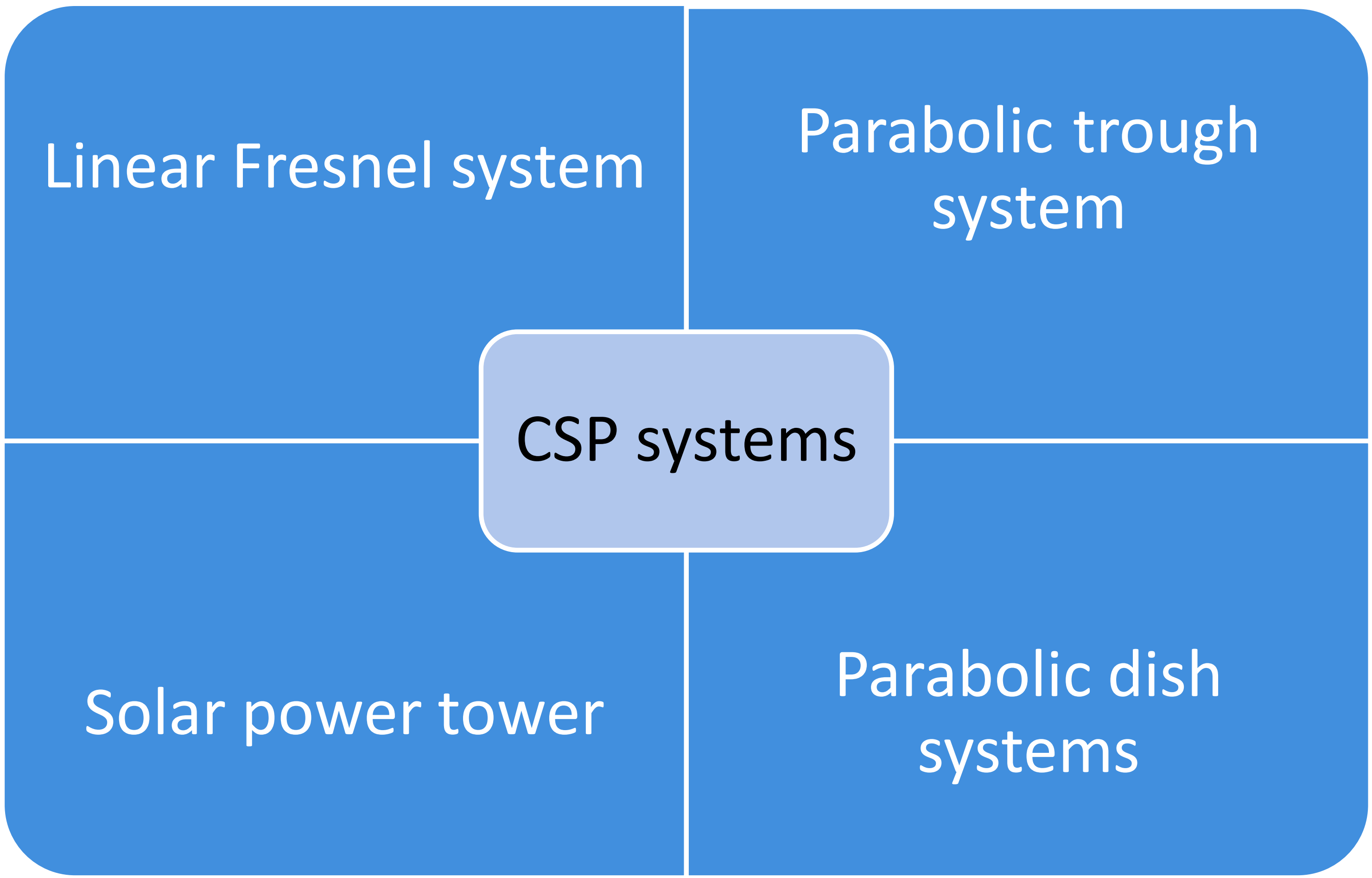
- Classified as solar thermal or PV systems.
- Can be direct or indirect collection systems.
- PV systems can be either flat-plate systems or concentrating systems.
- Small-scale PV desalination systems being used worldwide, particularly in remote areas and on islands.

PV – RO system



Source: Kim et al., 2013.

CSP desalination systems



Source: Bechtel Power Corp. et al., 2010.

Wind powered desalination

- More suitable for powering small-medium scale desalination operations (e.g., wind-RO combinations can produce 50–2,000 m3/day).
- Also suitable for coastal areas.
- Wind energy usually associated with the powering of the RO, ED, or MVC desalination processes.
- In MVC, the wind turbine’s mechanical energy is directly used for vapor compression without requiring a further conversion into electricity, increasing process efficiency.

Key messages

- Share of RE in the electricity generation sector increasing worldwide.
  - This is also true for the Arab countries.

- RE technologies consume less water than conventional sources when being used to produce electricity.
  - Water withdrawal similar in value to water consumed for RE technologies.

- Solar energy is the most popular type of RE for powering desalination.

- There are many potential RE-desalination combinations but only a select few are viable.
  - Solar stills, solar-multiple effect humidification, PV- RO, wind-RO, and CSP/MED are the combinations which are currently being applied as RE powered desalination or have more potential to be applied.

THANK YOU

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