TECHNOLOGIES TO IMPROVE WATER EFFICIENCY

Water-Energy Nexus Operational Toolkit: Resource Efficiency

20/02/2017
Outline

• Introduction
• Water efficiency in electricity production
• Water efficiency in oil and gas industry
• Water efficiency in industrial, commercial & institutional sectors
• Water efficiency in water production and distribution systems
• Key messages
Introduction

Water stress in the Arab countries

WATER STRESS BY COUNTRY

ratio of withdrawals to supply

- Low stress (< 10%)
- Low to medium stress (10-20%)
- Medium to high stress (20-40%)
- High stress (40-80%)
- Extremely high stress (> 80%)

This map shows the average exposure of water users in each country to water stress, the ratio of total withdrawals to total renewable supply in a given area. A higher percentage means more water users are competing for limited supplies. Source: WRI Aqueduct, Gassert et al. 2013
Total renewable water resources

Unmet water demand in Arab countries

**Source:** Created based on data from Immerzeel et al., 2011.
## Water reuse in the Arab countries

<table>
<thead>
<tr>
<th>Countries</th>
<th>Percentage of wastewater treated</th>
<th>Percentage of treated wastewater reused</th>
<th>Reused water as a percentage of total water withdrawn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>85.37</td>
<td>7.29</td>
<td>0.84</td>
</tr>
<tr>
<td>Bahrain</td>
<td><strong>100.00</strong></td>
<td><strong>36.30</strong></td>
<td>4.56</td>
</tr>
<tr>
<td>Egypt</td>
<td>79.79</td>
<td>23.33</td>
<td>1.02</td>
</tr>
<tr>
<td>Iraq</td>
<td>17.04</td>
<td>5.61</td>
<td>0.01</td>
</tr>
<tr>
<td>Jordan</td>
<td>94.87</td>
<td>91.89</td>
<td><strong>10.84</strong></td>
</tr>
<tr>
<td>Kuwait</td>
<td>95.60</td>
<td><strong>32.64</strong></td>
<td><strong>8.54</strong></td>
</tr>
<tr>
<td>Lebanon</td>
<td>1.29</td>
<td>50.00</td>
<td>0.15</td>
</tr>
<tr>
<td>Libya</td>
<td><strong>7.33</strong></td>
<td><strong>100.00</strong></td>
<td>0.92</td>
</tr>
<tr>
<td>Morocco</td>
<td>25.29</td>
<td>45.20</td>
<td>0.63</td>
</tr>
<tr>
<td>Oman</td>
<td>37.76</td>
<td>6.22</td>
<td>0.17</td>
</tr>
<tr>
<td>Qatar</td>
<td>14.86</td>
<td>65.15</td>
<td><strong>7.82</strong></td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>89.32</td>
<td>25.46</td>
<td>0.70</td>
</tr>
<tr>
<td>Syria</td>
<td><strong>40.15</strong></td>
<td><strong>100.00</strong></td>
<td>3.29</td>
</tr>
<tr>
<td>Tunisia</td>
<td>52.06</td>
<td>28.33</td>
<td>2.39</td>
</tr>
<tr>
<td>UAE</td>
<td><strong>90.80</strong></td>
<td><strong>54.63</strong></td>
<td><strong>6.20</strong></td>
</tr>
<tr>
<td>West Bank &amp; Gaza</td>
<td>60.00</td>
<td>18.13</td>
<td>1.30</td>
</tr>
<tr>
<td>Yemen</td>
<td>62.16</td>
<td>13.04</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Water efficiency in electricity production
Energy production is the 2nd largest use of water (after agriculture).

Globally, 90% of power generation is water-intensive.

75% of all industrial water withdrawals are for power production.

80% of global energy is produced by thermal power generation.

Water efficiency in electricity production

Water efficiency in electricity production

**Types of cooling processes**

<table>
<thead>
<tr>
<th>Cooling type</th>
<th>Water withdrawal</th>
<th>Water consumption</th>
<th>Capital cost</th>
<th>Plant efficiency</th>
<th>Ecological impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Once-through</td>
<td>Moderate</td>
<td>Intense</td>
<td>High</td>
<td>Less efficient</td>
<td>Low</td>
</tr>
<tr>
<td>Dry cooling</td>
<td>None</td>
<td>None</td>
<td>High</td>
<td>Efficient</td>
<td>Low</td>
</tr>
<tr>
<td>Wet cooling</td>
<td>Moderate</td>
<td>Intense</td>
<td>High</td>
<td>Efficient</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Sources:
- Electric Power Research Institute (EPRI), 2002
- Rodriguez et al., 2013
- Union of Concerned Scientists, n.d.

Source: Kohli and Frenken, 2011.
## Water efficiency in electricity production

### Water use in cooling processes

<table>
<thead>
<tr>
<th></th>
<th>Once-through</th>
<th>Recirculating</th>
<th>Dry-cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Coal (conventional)</td>
<td>20,000-50,000</td>
<td>100-317</td>
<td>500-1,200</td>
</tr>
<tr>
<td></td>
<td>480-1,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Natural gas</td>
<td>7,500-20,000</td>
<td>20-100</td>
<td>150-283</td>
</tr>
<tr>
<td>(combined cycle)</td>
<td></td>
<td></td>
<td>130-300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-4</td>
</tr>
<tr>
<td>Nuclear</td>
<td>25,000-60,000</td>
<td>100-400</td>
<td>800-2,600</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>600-800</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

**Sources:** Created based on data from Macknick et al., 2012; Union of Concerned Scientists, n.d.

Unit: Gallons of water required per megawatt-hour of electricity produced

W: Withdrawal; C: Consumption.
Water efficiency in electricity production

**Water consumption factors of conventional power plants**

![Bar chart showing water consumption factors for different power plants types](chart.png)

- **Generic**: 672 gal/MWh, 610 gal/MWh
- **Combined Cycle**: 826 gal/MWh, 240 gal/MWh
- **Steam**: 240 gal/MWh
- **Combined Cycle with CCS**: 687 gal/MWh, 471 gal/MWh
- **Subcritical**: 493 gal/MWh
- **Supercritical**: 42 gal/MWh
- **IGCC**: 372 gal/MWh
- **Subcritical with CCS**: 942 gal/MWh
- **Supercritical with CCS**: 846 gal/MWh
- **IGCC with CCS**: 540 gal/MWh

*Source: Macknick et al., 2011.*
Water efficiency in electricity production

Combined plants

Increasing water efficiency through decreasing waste heat

Improving power plant system component efficiencies

Reusing heat to prevent it from being dissipated

Combined power and desalination plants

Combined heat and power (CHP) plants

• Combined plants can have efficiencies as high as 90%.
• Alternative water sources can help improve water efficiency.

Sankey diagram of CHP and conventional power plants; Source: Rodriguez et al., 2013.
Water efficiency in oil and gas industry
Oil and gas industry

Embedded water in oil and gas processes

Oil Drilling

Transport (e.g., raff, tanker, truck, pipeline)

Oil Refining

Transport (e.g., raff, tanker, truck, pipeline)

End Use
Industrial
Commercial
Residential
Public Utilities
Transportation

Evaporation

Water Input

Produced Water

Wastewater Discharge - Direct and Indirect

Water Source A

Transport (e.g., raff, tanker, truck, pipeline)

Water Input

Wastewater Discharge - Direct and Indirect

Water Source B

Oil and gas industry

Water coefficients in primary energy production

**PRIMARY RECOVERY**
- Artificial Lift
- Natural Drive

**SECONDARY RECOVERY**
- Water Flooding
- Pressure Maintenanc

**TERTIARY RECOVERY / ENHANCED OIL RECOVERY (EOR)**
- **THERMAL**
  - Steam
  - In-situ combustion
- **CO2**
- **GAS**
  - Natural Gas
  - Nitrogen
- **CHEMICAL**
  - Alkaline
  - Polymer
  - Surfactants
  - Microbial

<30% recovery
20-60% recovery
50-80% recovery
Oil and gas industry

**Enhanced Oil Recovery (EOR)**

Injection water required (gallons of water/gallons of crude oil) for various oil recovery technologies.

- **Thermal recovery**
  - Steam injection: 5.4
  - Forward combustion/air injection: 1.9

- **Gas injection**
  - CO₂ injection: 13

- **Chemical injection**
  - Caustic injection: 3.9
  - Micellar polymer injection: 343.1

Source: Xylem, 2014.
Oil and gas industry

Fracking

The amount of water required can vary significantly according to the type of shale and well characteristics.

Tunisia, Egypt, Saudi Arabia and Jordan have plans to extract shale gas, while Oman and Algeria, have already begun fracking operations.
Oil and gas industry

Water reuse in the oil and gas industry

Water efficiency in the oil and gas industry can be improved by using pipelines, onsite treatment, and reusing wastewater and produced water.

- Reusing produced water facilitates automated water resources management.
- Reusing produced water provides a stable water supply and more resilient operations.
- Produced water reuse is becoming more prevalent as policies on water use and discharge are becoming more stringent.
Oil and gas industry

Consolidation practices

- Consolidation: Well development operations performed simultaneously for several wells.
- Such practices can decrease the need for fresh water by approximately 2 million oil barrels by recycling about 80% of completion fluids.

### Multi-Well Pad Savings

<table>
<thead>
<tr>
<th></th>
<th>2 Well Pad</th>
<th>4 Well Pad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings per well</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rig moves</td>
<td>$100,000</td>
<td>$150,000</td>
</tr>
<tr>
<td>Location</td>
<td>$50,000</td>
<td>$70,000</td>
</tr>
<tr>
<td>Drill pipe handling</td>
<td>$25,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>Frac costs</td>
<td>$50,000</td>
<td>$60,000</td>
</tr>
<tr>
<td>Daily rentals</td>
<td>$10,000</td>
<td>$15,000</td>
</tr>
</tbody>
</table>

Legend:
- Blue: Rig moves
- Red: Location
- Green: Drill pipe handling
- Purple: Frac costs
- Cyan: Daily rentals

Completion

Drilling
Water efficiency in industrial, commercial & institutional sectors
Example: The minimum estimate of potential savings from increased water efficiency in the industrial, commercial and institutional sectors of California would be sufficient to fulfil the annual water requirements of the whole city of Los Angeles (both residential and non-residential applications).
Industrial, commercial & institutional sectors

Potential savings from water efficient technologies

- Cooling Tower Conductivity Controller
- High-Efficiency Clothes Washer (Common-Area Laundry)
- Landscape Irrigation (e.g., Smart Controllers and Sensors, Xeriscaping)
- Low-Flow Showerhead
- Tunnel Washer (Industrial Laundry)
- Water-Efficient Commercial Dishwasher
- Water-Efficient Pre-Rinse Spray Valve

Source: Cohen et al., 2009.
Water reuse

Recycling water – Considerations

End use
• Groundwater recharge
• Agricultural reuse
• Industrial reuse

Application description
• Non-Potable Reuse
• Food/Non-food crops
• Once-Through Cooling

Treatment required
• Primary
• Secondary
• Filtration
• Disinfection
• Soil Aquifer Treatment

Industrial, commercial & institutional sectors

Greywater recycling systems

Schematic diagram of a greywater recycling system; Source: Tanked Australia, 2007.
Industrial, commercial & institutional sectors

**Faucets and Toilets**

The Aqus(TM) WaterSaver technology which uses sink greywater for toilets; *Source*: Lepisto, 2006.
Water efficiency in water production and distribution systems
Water production and distribution systems

Water efficient greenhouses
Water production and distribution systems

Aquaponics

- Type of hydroponics.
- Uses 90% less water than traditional farming.
Water production and distribution systems

Vertical farming

- Can use up to 95% less water than traditional farming.
- One tower produces the same harvest as 25m² of farm land.
- 100 towers produce as much harvest as farmland the size of a football field.

Water is directed into the water pulley system to rotate the racks in the tower three times a day. This ensures that every rack of plants receives sufficient sunlight.

Rainwater and recycled water are collected in an overhead tank.

The patented water pulley system makes use of flowing water and gravity to rotate the racks.

As racks rotate, the plants are watered by micro-sprinklers three times a day.

The water is then recycled to power the generator.

A generator powers a pump, which redirects water into the tank.
Irrigation systems

Efficiency of application for various irrigation methods; *Source:* Heatley and Ritchie, 2006.

Typical water losses from a pressurized irrigation system; *Source:* Heatley and Ritchie, 2006.

<table>
<thead>
<tr>
<th>Loss component</th>
<th>Range</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaking pipes</td>
<td>0-10%</td>
<td>0-1%</td>
</tr>
<tr>
<td>Evaporation in the air</td>
<td>0-10%</td>
<td>&lt;3%</td>
</tr>
<tr>
<td>Wind-drift out of target area</td>
<td>0-20%</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Interception and evaporation from the crop/pasture</td>
<td>0-10%</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Surface run-off</td>
<td>0-10%</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>Uneven/excessive application depths and rates</td>
<td>5-80%</td>
<td>5-30%</td>
</tr>
</tbody>
</table>
Water production and distribution systems

Intelligent metering systems

- These employ "smart meters".
- It is estimated that energy savings of up to 30% can be achieved by combining intelligent metering with occupants' behavioral change.
- Some Arab countries are in the pilot phase of adopting such technologies (e.g., Saudi Arabia and Qatar).
- UAE stands out as a frontrunner (e.g., by 2013, Abu Dhabi had already completed its first phase of smart meters implementation for both electricity and water).

Hierarchy for water efficiency strategies; Source: Boyle et al., 2013.
Water production and distribution systems

Intelligent water metering systems

- IM
  - Meters for water use data capture
    - Displacement meters
    - Velocity meters
    - Compound (or combination meters)
    - Electromagnetic meters
  - Communication systems
Key messages

• There is no ideal efficiency solution for all ESCWA member countries.
  o Strategies must be assessed with reference to the respective situation.

• Recycling of wastewater is a strategy that can be implemented by various sectors.
  o As environmental standards for discharged waters become more stringent, recycling water becomes more feasible.

• Water consumption can be reduced in electricity generation processes by addressing various parameters. Examples:
  o Cooling types
  o Combined cycle arrangements

• Several technological options for more water efficient water distribution (e.g., IM systems), particularly in the agricultural sector, are becoming more popular.
THANK YOU