Water Use in Concentrating Solar Power (CSP) Systems

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Water Supply Constraints Coincide with Best CSP Plant Locations in the US

Water Sustainability Index - EPRI
What is CSP?

Concentrating Solar Power

Large

Centralized

Solar power

CSP can produce electricity very much like conventional technologies
CSP: Technology types

- Parabolic trough
- Linear Fresnel
- Power tower
- Dish/Stirling
CSP cooling technology options

Wet Cooled (Cooling Towers)

Dry Cooled (Air Cooled Condensers)

Hybrid Cooled (Both cooling towers and air cooled condensers)
CSP technologies with thermal energy storage are dispatchable like conventional electricity generating technologies.

Thermal energy storage systems with molten salts allow electricity to be generated when the sun is not shining.

Electricity can be “dispatched” when it is needed most throughout the day.
How CSP Works (parabolic trough)
How CSP Uses Water (parabolic trough)

- Cleaning: ~20-40 gallons/MWh
- Makeup: ~30-60 gallons/MWh
- Cooling: ~750-950 gallons/MWh
How CSP Uses Water  (parabolic trough)

Cleaning  
~20-40 gallons/MWh

Cooling:  
~0 gallons/MWh

Makeup  
~30-60 gallons/MWh

Air Cooled Condenser
Water Consumption of CSP technologies
CSP water consumption intensities depend on technology and cooling system

CSP Technology-Specific Water Consumption Values

Source: Macknick et al., forthcoming
Average Water Consumption Factors (gal/MWh) Cooling Tower and Dry Cooled Systems

Source: Macknick et al. (forthcoming)
CSP technologies have lower water use per land area than many other land-uses

Sources:
Going forward, what is the most appropriate cooling technology to use for CSP?

Dry-cooled and hybrid cooling systems mitigate water impacts, but there are tradeoffs.
Relative rankings of different CSP cooling technologies show complex tradeoffs

<table>
<thead>
<tr>
<th>Cooling Type</th>
<th>Installed Cost</th>
<th>Operational Costs</th>
<th>Parasitic Loads</th>
<th>Effective Cooling in Arid Climates</th>
<th>Water Consumption</th>
<th>Cooling Tower Blowdown Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet</td>
<td><strong>Best</strong></td>
<td><strong>Best</strong></td>
<td><strong>Best</strong></td>
<td><strong>Best</strong></td>
<td><strong>Best</strong></td>
<td><strong>Best</strong></td>
</tr>
<tr>
<td>Dry (ACC)</td>
<td><strong>In Between</strong></td>
<td><strong>Best</strong></td>
<td><strong>In Between</strong></td>
<td><strong>In Between</strong></td>
<td><strong>Best</strong></td>
<td><strong>Worst</strong></td>
</tr>
<tr>
<td>Hybrid</td>
<td><strong>Worst</strong></td>
<td><strong>Worst</strong></td>
<td><strong>Worst</strong></td>
<td><strong>Worst</strong></td>
<td><strong>Worst</strong></td>
<td><strong>In Between</strong></td>
</tr>
</tbody>
</table>

Adapted from Turchi et al. (Forthcoming 2010)
NREL contracted with WorleyParsons Group to examine the water consumption of parabolic trough plants in different locations and with different cooling options (Turchi et al., 2010 in preparation)

<table>
<thead>
<tr>
<th>Location</th>
<th>Design Basis</th>
<th>Storage</th>
<th>Cooling Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daggett, CA</td>
<td>Constant Capacity: 103 MW</td>
<td>6.3 hrs</td>
<td>Wet, dry</td>
</tr>
<tr>
<td>Las Vegas, NV</td>
<td>Constant Heat Input: 562,440 m² solar field</td>
<td>None</td>
<td>Wet, dry, hybrid</td>
</tr>
<tr>
<td></td>
<td>Constant Heat Input: 931,950 m² solar field</td>
<td>6 hrs</td>
<td>Wet, dry, hybrid</td>
</tr>
<tr>
<td></td>
<td>Constant Capacity: 125MW</td>
<td>4 hrs</td>
<td>Wet, dry</td>
</tr>
<tr>
<td>Alamosa, CO</td>
<td>Constant Heat Input: 905,790 m² solar field</td>
<td>6 hrs</td>
<td>Wet, dry, hybrid</td>
</tr>
</tbody>
</table>
Climatic conditions affect CSP performance and cooling technology performance

Hotter areas have lower efficiencies for wet cooled systems and have greater performance penalties for switching to dry cooling.

Adapted from Turchi et al. (Forthcoming 2010)
Climatic conditions affect CSP water consumption rates

Hotter areas consume more water per unit of electric output

Water consumption rates for different cooling systems (gal/MWh)

- Dry Cooling
- Hybrid Cooling
- Wet Cooling

*Hybrid cooling water use rates for Las Vegas are based on 50% reduction in water use

Adapted from Turchi et al. (Forthcoming 2010)
Climatic conditions affect CSP costs of energy generation

Compared to wet-cooled System, LCOE increase ranges from 2.5% to 7.5%

Adapted from Turchi et al. (Forthcoming 2010)
Summary of CSP water issues

CSP technologies have the potential to play a large role in a clean energy economy

Wet cooled CSP systems have a lower water intensity than carbon capture and storage (CCS) systems

CSP technologies can reduce overall water consumption on former agricultural lands

Careful consideration regarding technology choices is required on a site-by-site basis

Dry cooling decreases output in hot areas by ~5%, and less in cooler areas, if an appropriate air-cooled condenser size is chosen

Dry cooling decreases water consumption by ~92%

Shift to dry cooling raises Levelized Cost of Energy (LCOE) by 2.5% to 7.5% depending on climate
Other research and opportunities to minimize water impacts of CSP

Wash water capture and reuse

Utilizing alternative sources of water for cooling

Increasing system efficiencies

Alternative hybrid cooling options
Thank you

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Useful websites:
NREL CSP homepage: http://www.nrel.gov/csp/
Solar PEIS homepage: http://solareis.anl.gov/
SolarPaces homepage: http://www.solarpaces.org/