National Renewable Energy Laboratory
Innovation for Our Energy Future

Concentrating Solar Power (CSP)

CA Desert Renewable Energy Conservation Plan Workshop,

Ontario, CA
April 22, 2010

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Outline

- CSP Technology Overview
  - Parabolic Troughs
  - Power Towers
  - Dish / Engine Systems
  - CSP comparison with Photovoltaics (PV)
  - Water consumption, land use

CSP: The Other Solar Energy

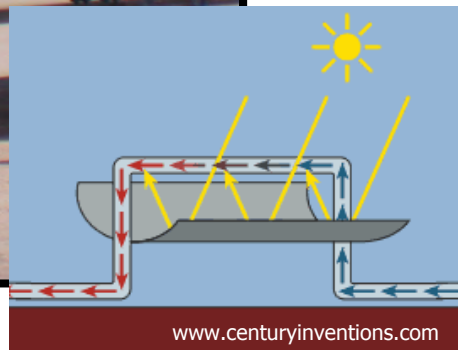
Parabolic trough

Linear Fresnel

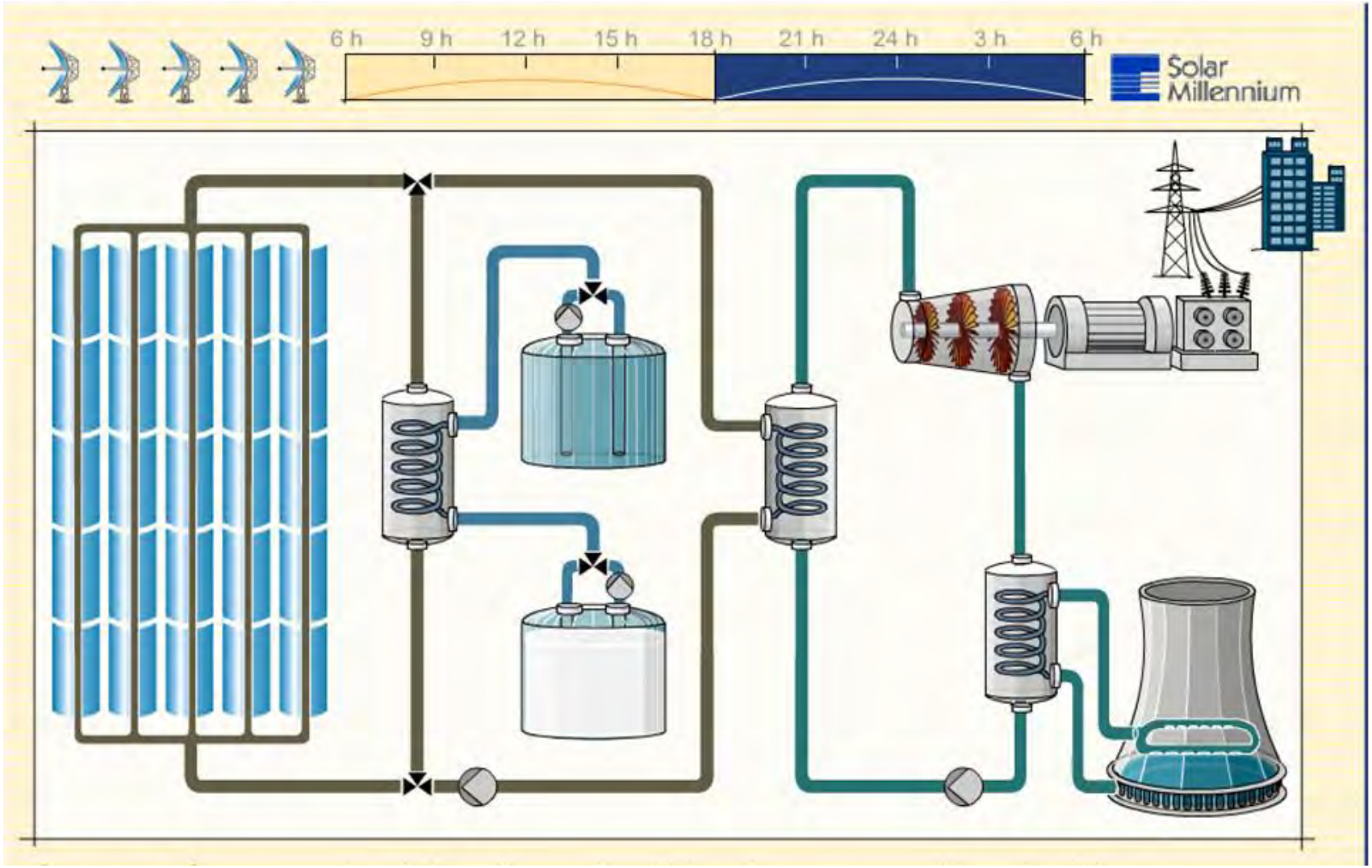
Power tower

Dish/Stirling

Parabolic Trough



Parabolic Trough Plant with Thermal Energy Storage



64 MW Acciona Nevada Solar One (2007)
Nevada, USA

50 MW Andasol 1 with 7-hr Storage (2009)
Andalucía, Spain

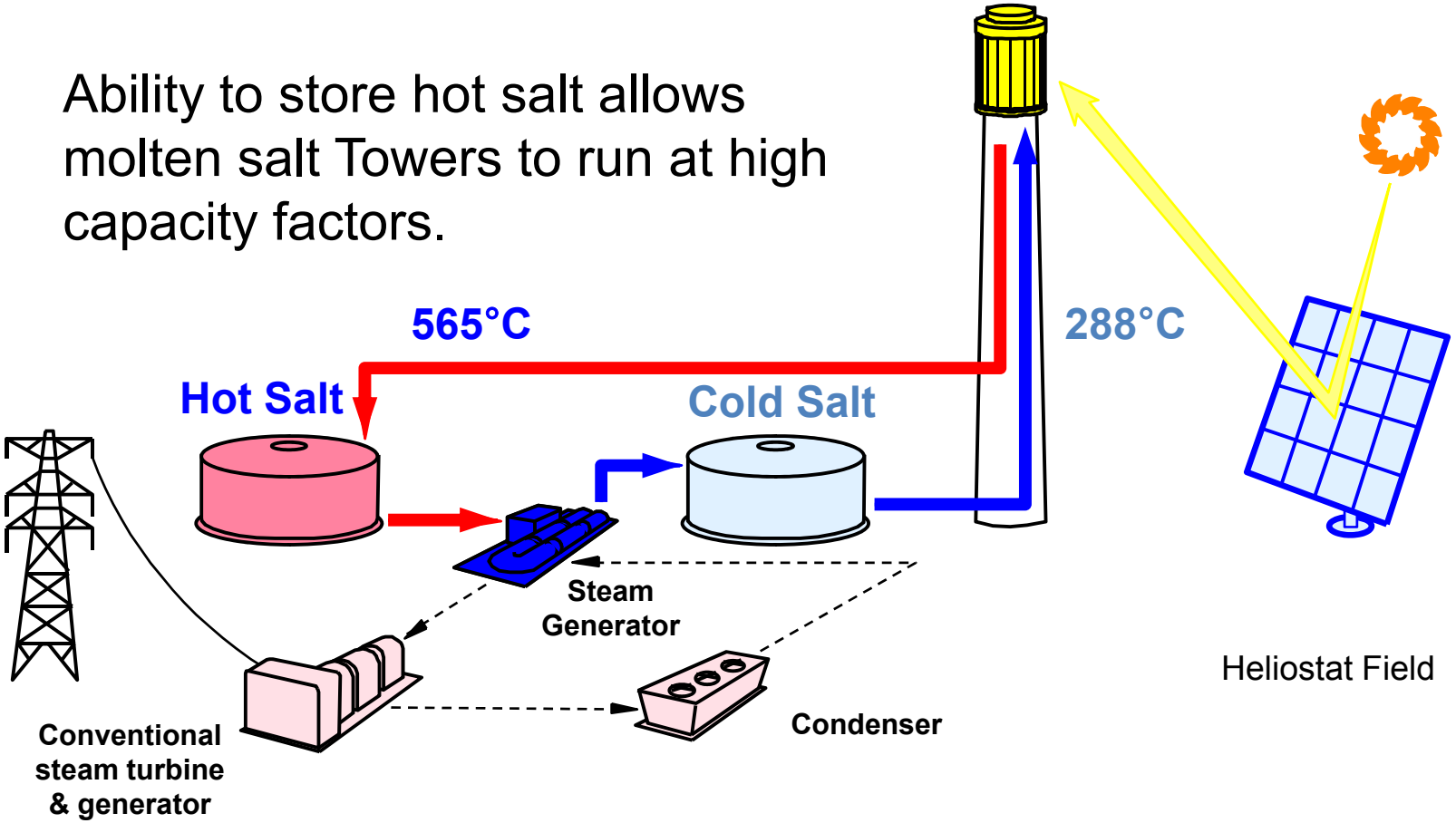
Power Tower (Central Receiver)

Different design approaches:

- Direct Steam Generation
  - Abengoa PS10 (Spain)
  - Abengoa PS20 (Spain)
  - BrightSource (USA/Israel)
  - eSolar (USA)
- Molten Salt
  - Solar Two (USA demo)
  - SolarReserve (USA)
- Air Receiver
  - Jülich (Germany)

Molten Salt Power Tower

Ability to store hot salt allows molten salt Towers to run at high capacity factors.



Power Tower Pilot Plants

6 $MW_{thermal}$ BrightSource
Negev Desert, Israel

5 MWe eSolar
California, USA

Dish/Stirling Engine Systems

Tessera Solar 1.5MW Maricopa Plant, Arizona

Technology Comparison

	Trough	Power Tower	Dish / Engine	PV
Typical Operating Temp	390C	565C	800C	n/a
Utility scale (>50 MW)	x	x	x	x
Distributed (<10MW)			x	x
Energy Storage	x	x		
Water use for cleaning	x	x	x	x
Water use for cooling	preferred	preferred		
Land Use (acre/MW)*	5-9	3-9	8-9	5-9
Land Slope	<3%	<5%	<5%	<5%
Technical maturity	medium	low	low	low to high

* Dependent on location and storage, values shown based on plants or announced projects

Wet- and Dry-cooled Condensers

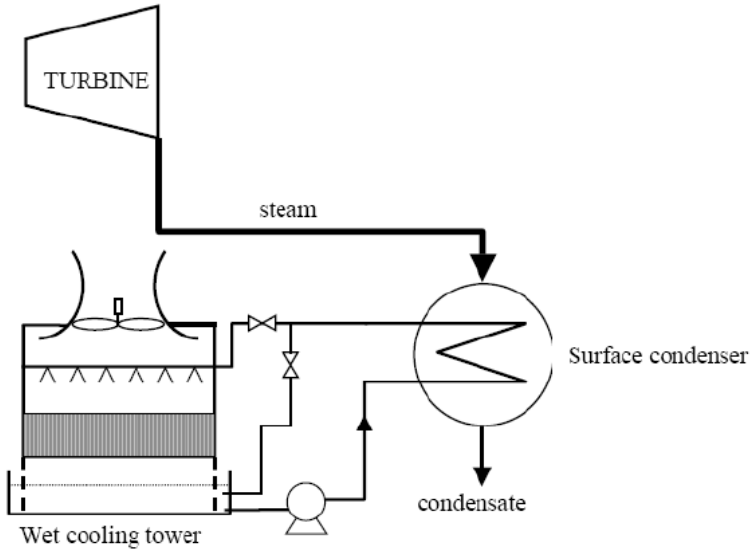


Figure 1 Schematic Diagram of Wet Heat Rejection System

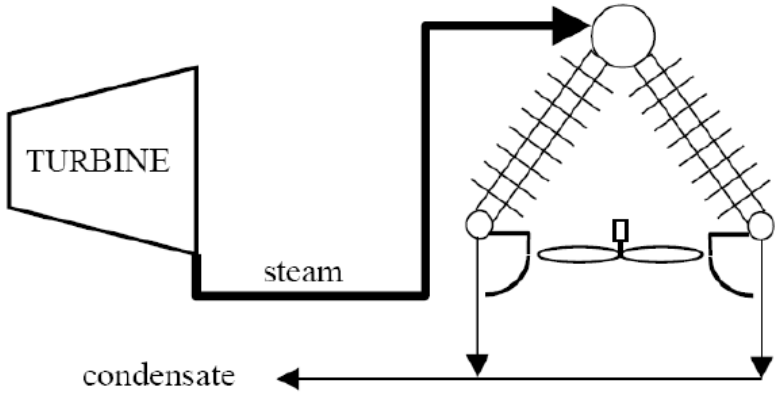
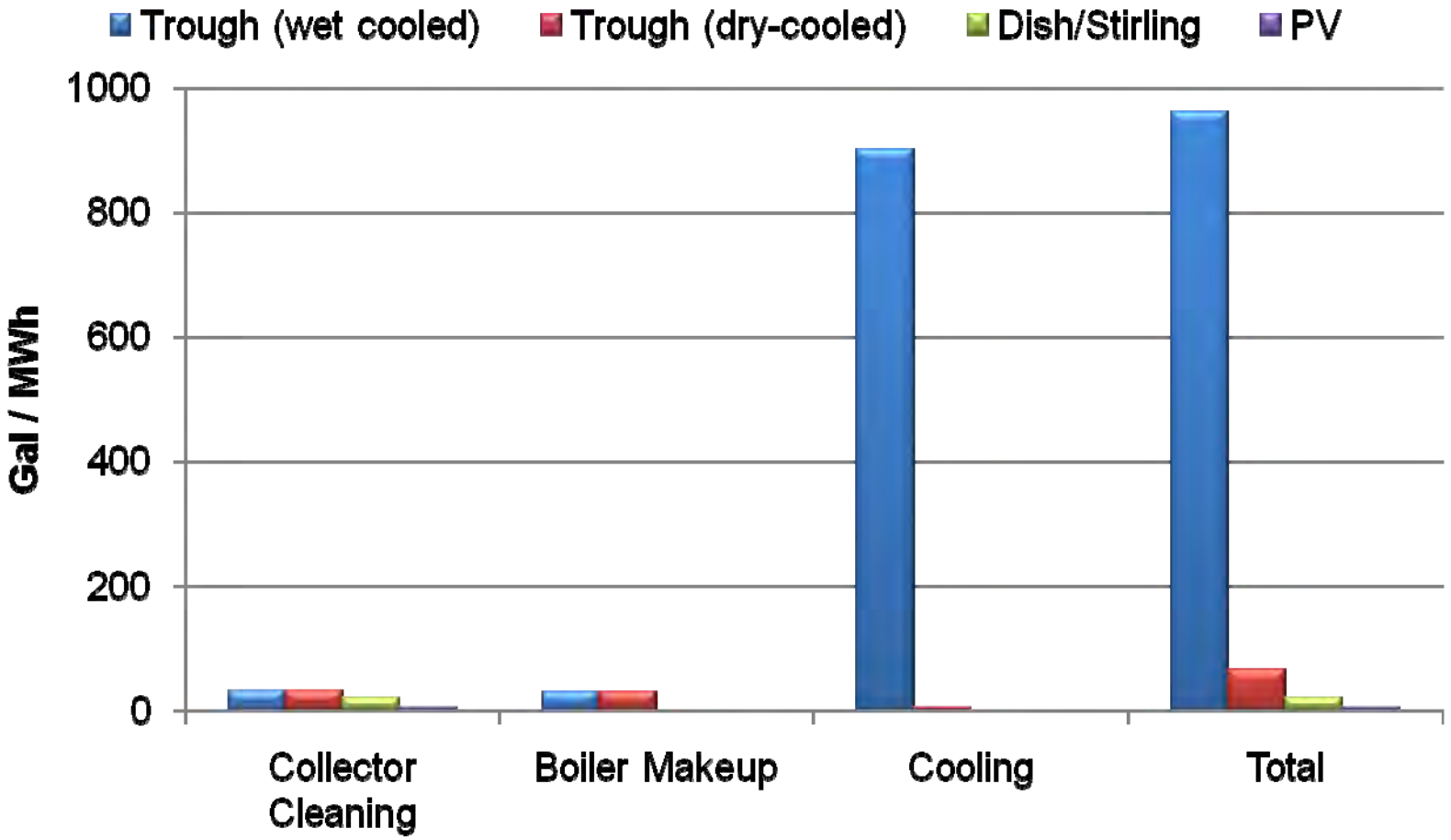


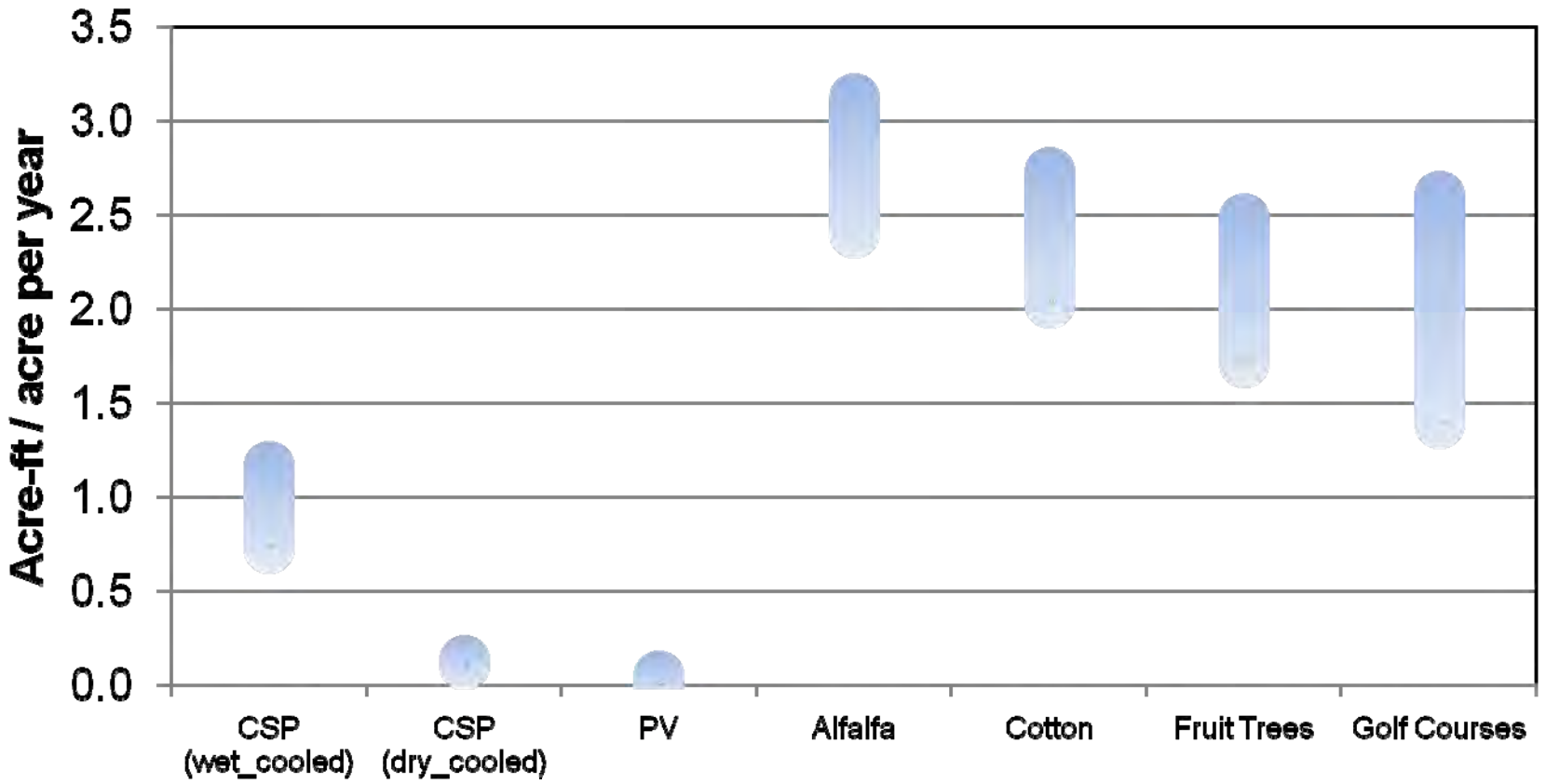
Figure 2 Schematic Diagram of Dry Heat Rejection System

Water Usage of Solar Technologies



Reference: DOE Solar Vision Study 2010, in preparation
Power Tower Cooling values approx. 20% lower than troughs
Values representative; specific usage varies by plant.

Water Use per Land Area



Sources:
CSP: Reducing Water Consumption of CSP Electricity Generation, Report to Congress 2009.
Crops: Blaney, Monthly Consumptive use of Water by Irrigated Crops & Natural Vegetation, 1957.
Golf : Watson et al., The Economic Contributions of Colorado's Golf Industry: Environmental Aspects.

Cooling Comparison Summary

Type	Advantages	Disadvantages
Wet	Lowest cost Low parasitic loads Small footprint Best cooling, especially in arid climates	High water consumption Water treatment and blowdown disposal required Plume can cause problems
Dry	No water consumption No water treatment required Lower O&M costs	More expensive equipment Higher parasitic loads Larger footprint Poorer cooling at high dry-bulb temps (turbine derate)
Hybrid	Less water consumption Potentially less expensive than dry-cooling Maintain good performance during hot weather	Complicated system involving wet and dry cooling Same disadvantages of wet system, but to lesser degree

Summary

- Trough and Power Tower technologies are unique in their ability to incorporate energy storage.
- Trough and Power Tower technologies prefer to use wet cooling (lower cost, higher efficiency).
- Dry-cooling can reduce water consumption by 90+%, but increases capital cost and decreases plant efficiency. Increase to levelized cost of electricity is 3% to 8% depending on location.
- Dish/Engine and PV systems use water only for collector cleaning.
- All solar plants use less water than typical SW crops
- Land usage of all utility-scale solar technologies is around 5-10 acres per MW.

Thank you!

For more information see:

http://www.nrel.gov/csp/

http://maps.nrel.gov/

http://solareis.anl.gov/

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