IVANPAH: The World's Largest Concentrated Solar Thermal Facility

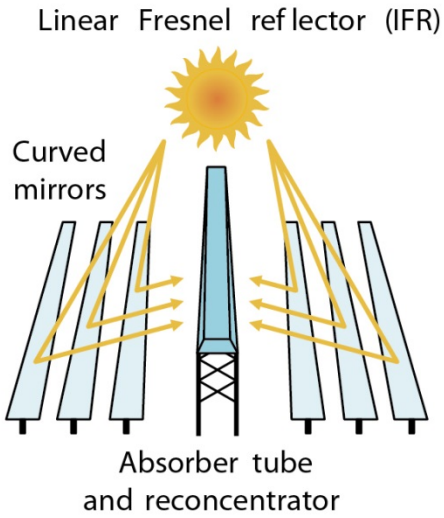
ACC Users Group Annual Conference 2017
Laura Sterk

nrg

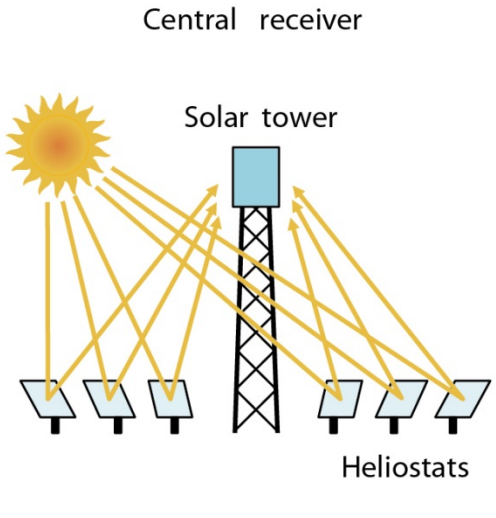
Concentrated Solar Power (CSP)

Main CSP Technologies

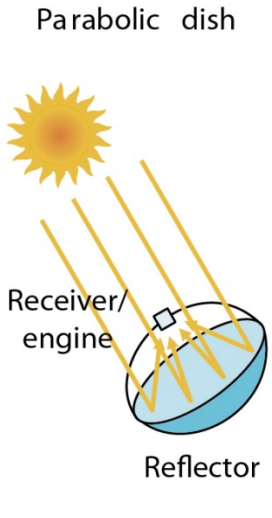
Linear Fresnel Reflectors



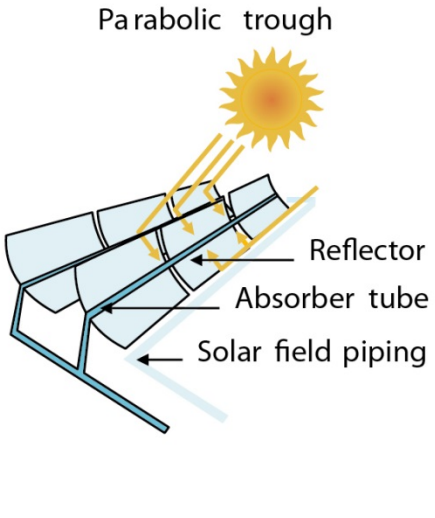
Tower



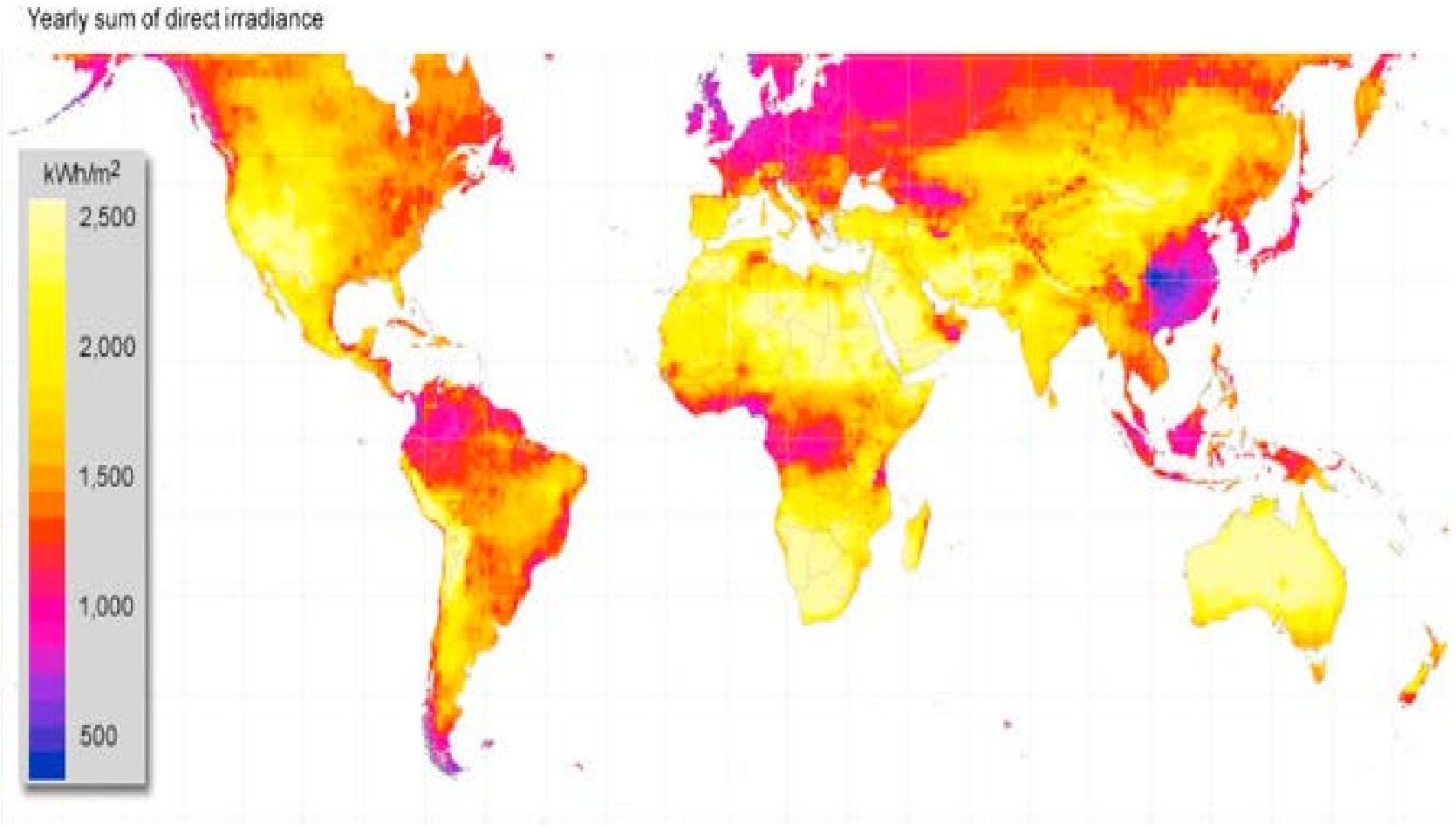
Parabolic Dishes



Parabolic Trough



Global Insolation



Global Sites-Power Tower

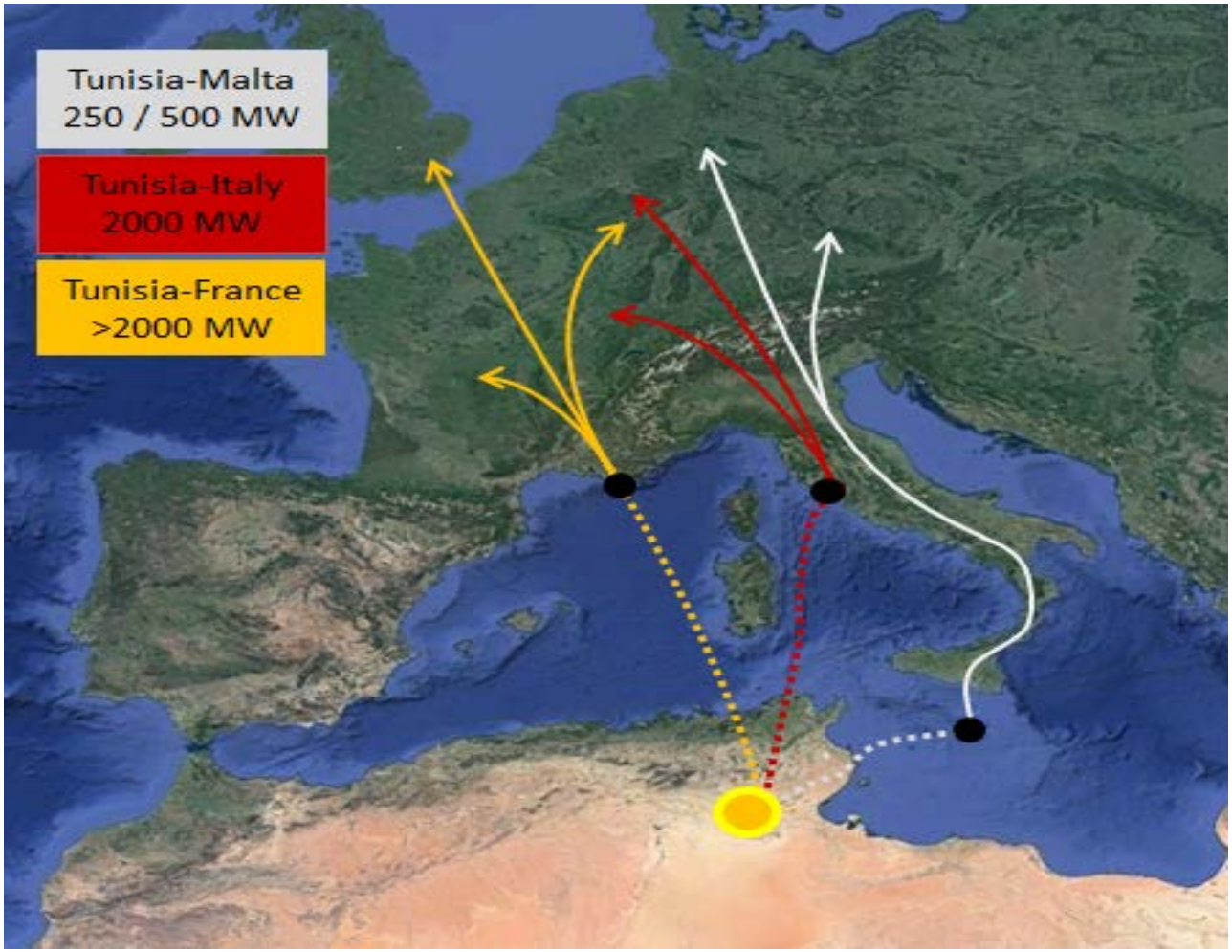
Existing solar towers

- IVP-394 MW 3 Towers—currently largest in the world
- Cresent Dunes 110 MW 1 Tower –molten salt storage (10hrs)
- Spain 10-20 MW, Africa 50 MW, Turkey 1 MW, Germany 1.5 MW

New projects

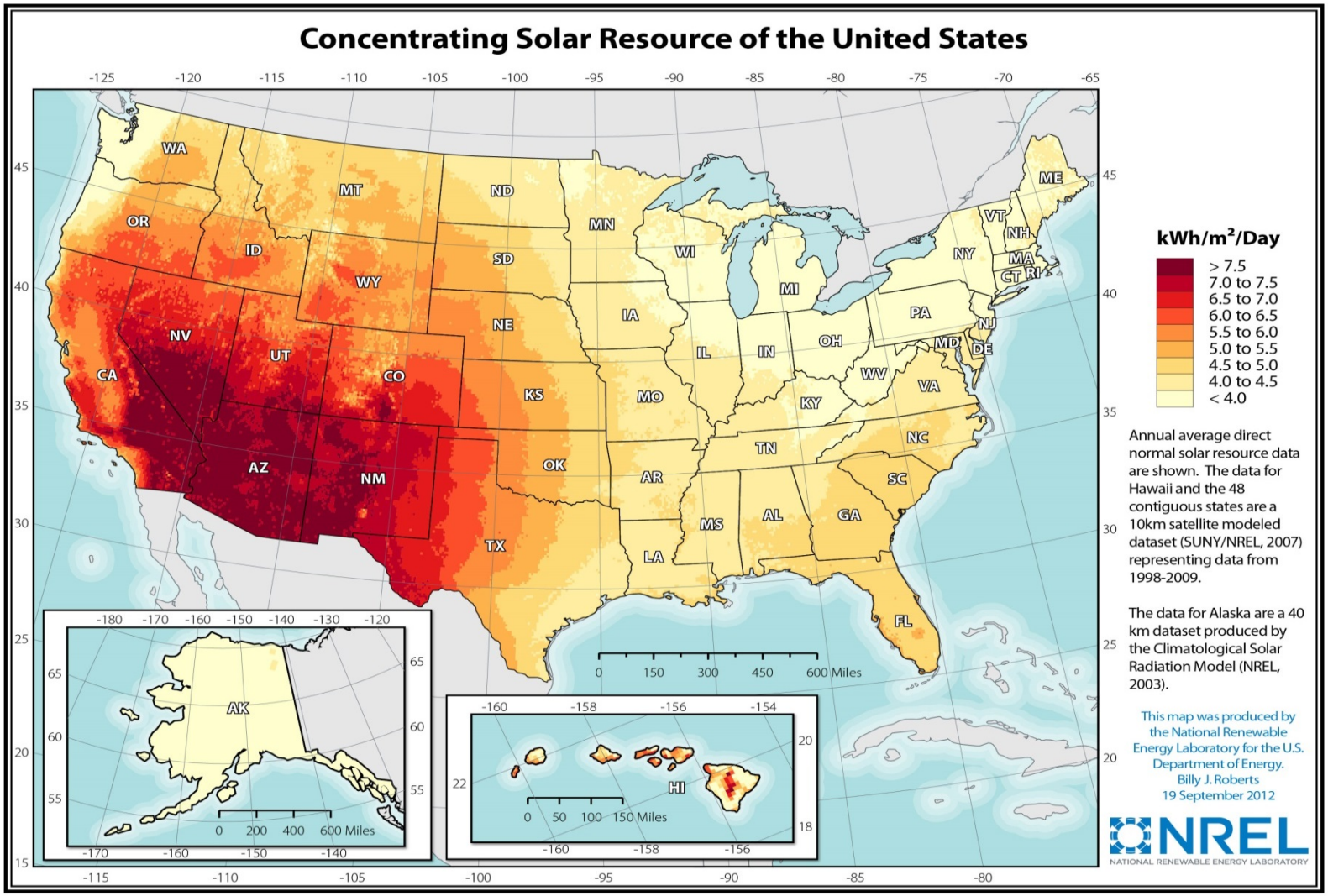
- Israel- 121 MW Ashalim 1 Tower
- China-135 MW The Huanghe Qinghai Delingha Solar Thermal Power Generation Project -2 Towers up to 6
- Dubai-Mohammed Bin Rashid Al Maktoum Solar Park- 9 Towers
- Morocco-135 MW

Tunisia Sahara Desert North Africa



Tunisia Sahara Desert North Africa

Incident radiation



Ivanpah Organization

Solar Partners Holdco, LLC - Equity Investors

- NRG
- Google
- BrightSource

Three Individual Projects

- Solar Partners II – Ivanpah #1 - ~25 yr PPA with PG&E
- Solar Partners I – Ivanpah #2 - ~25 yr PPA with SCE
- Solar Partners VIII – Ivanpah #3 - ~25 yr PPA with PG&E

Site

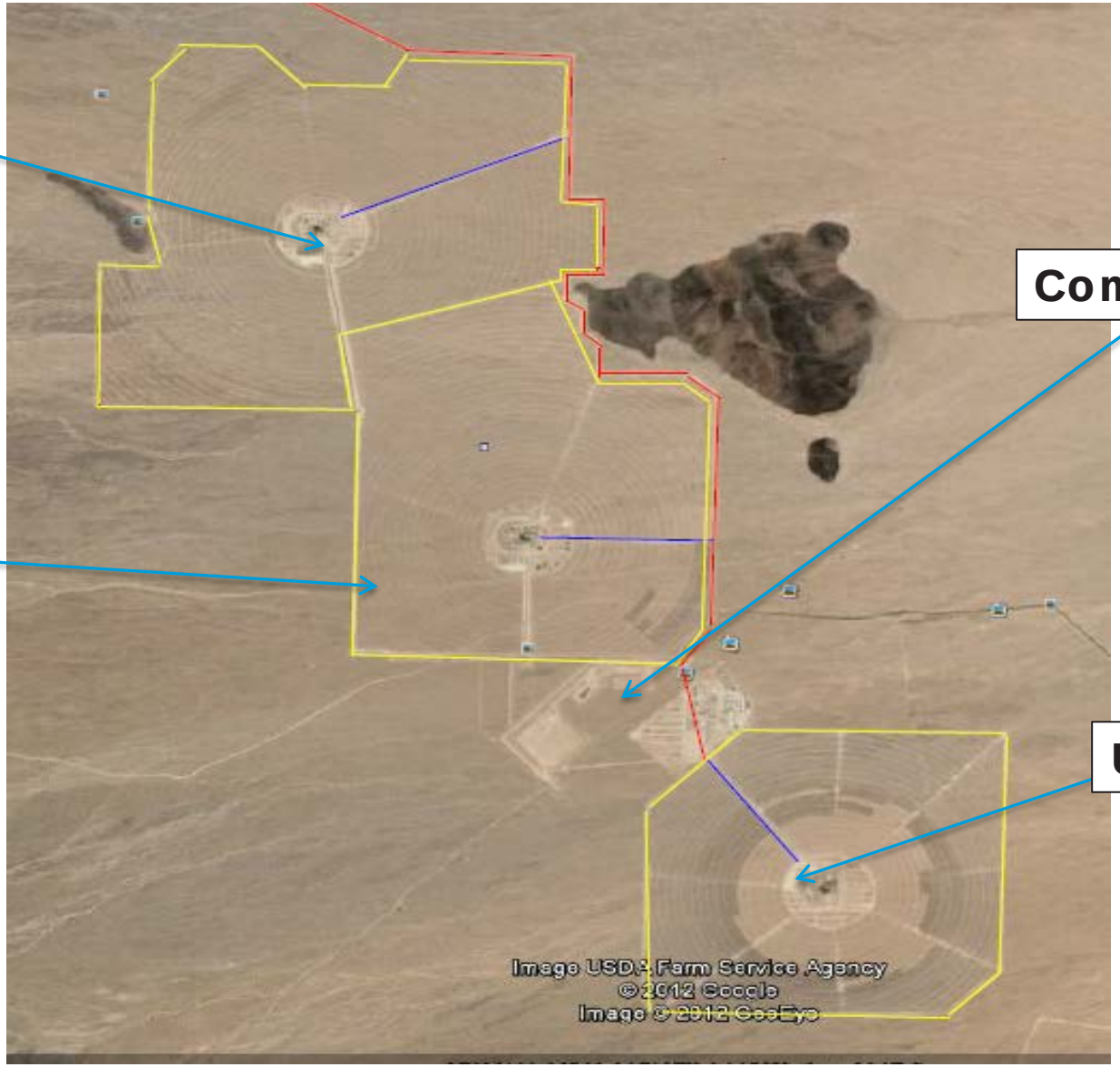
Geography and Footprint

- Project site is 3500 acres
- Each unit about 900 acres
- Unit 1 to Unit 3 Tower = 3.2 miles
- Edge of U1 SF to edge of U3 SF = 5 miles

Tower

- Total Height is 459’
- ~325 ft steel structure w/ the boiler on top

Project Layout Solar Field



Overall Rankine/Steam Cycle

- LP feedwater heaters (115F-330F)

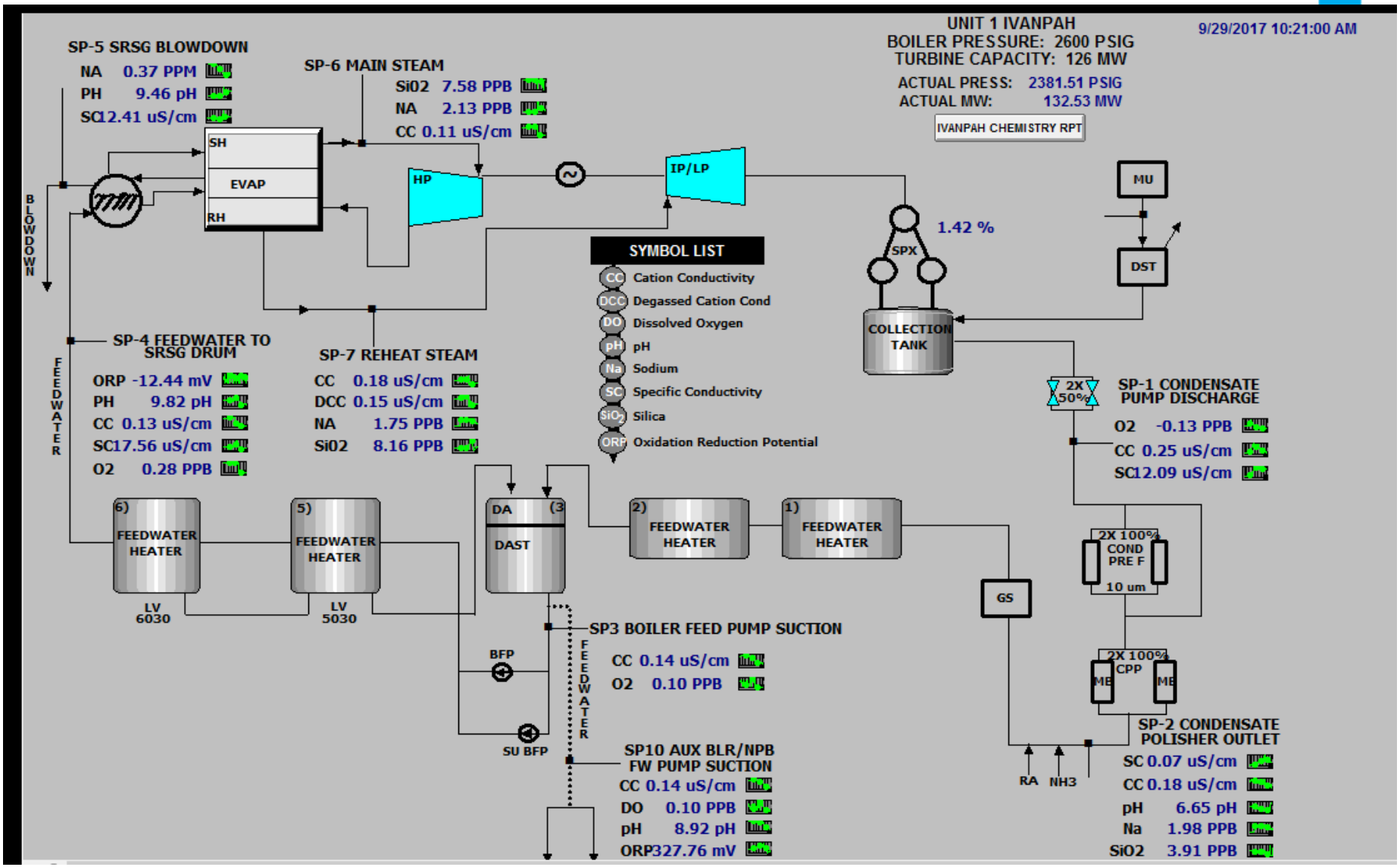
  2 closed, 1 open (deareator)

- 3 vertical HP feedwater heaters (330F-491F)
- SRSG boiler (542F)

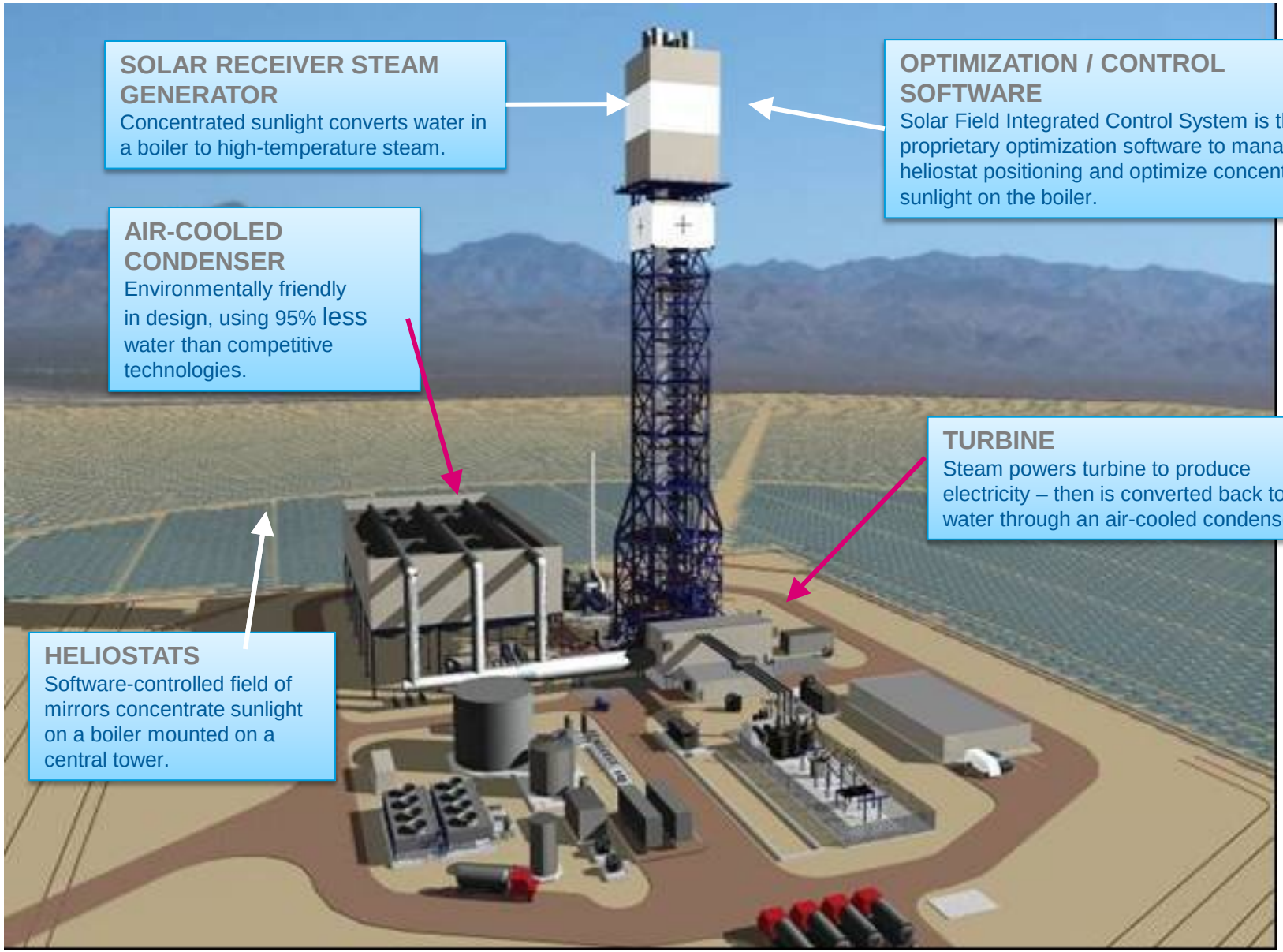
  evaporator (542F), superheat (977F), reheat (834F)

- Auxiliary boiler (903F)
- NPB (steam seals)
- ACC (100F)

Cycle Chemistry



Power Block Configuration



SOLAR RECEIVER STEAM GENERATOR
Concentrated sunlight converts water in a boiler to high-temperature steam.

OPTIMIZATION / CONTROL SOFTWARE
Solar Field Integrated Control System is the proprietary optimization software to manage heliostat positioning and optimize concentrated sunlight on the boiler.

AIR-COOLED CONDENSER
Environmentally friendly in design, using 95% less water than competitive technologies.

TURBINE
Steam powers turbine to produce electricity – then is converted back to water through an air-cooled condenser.

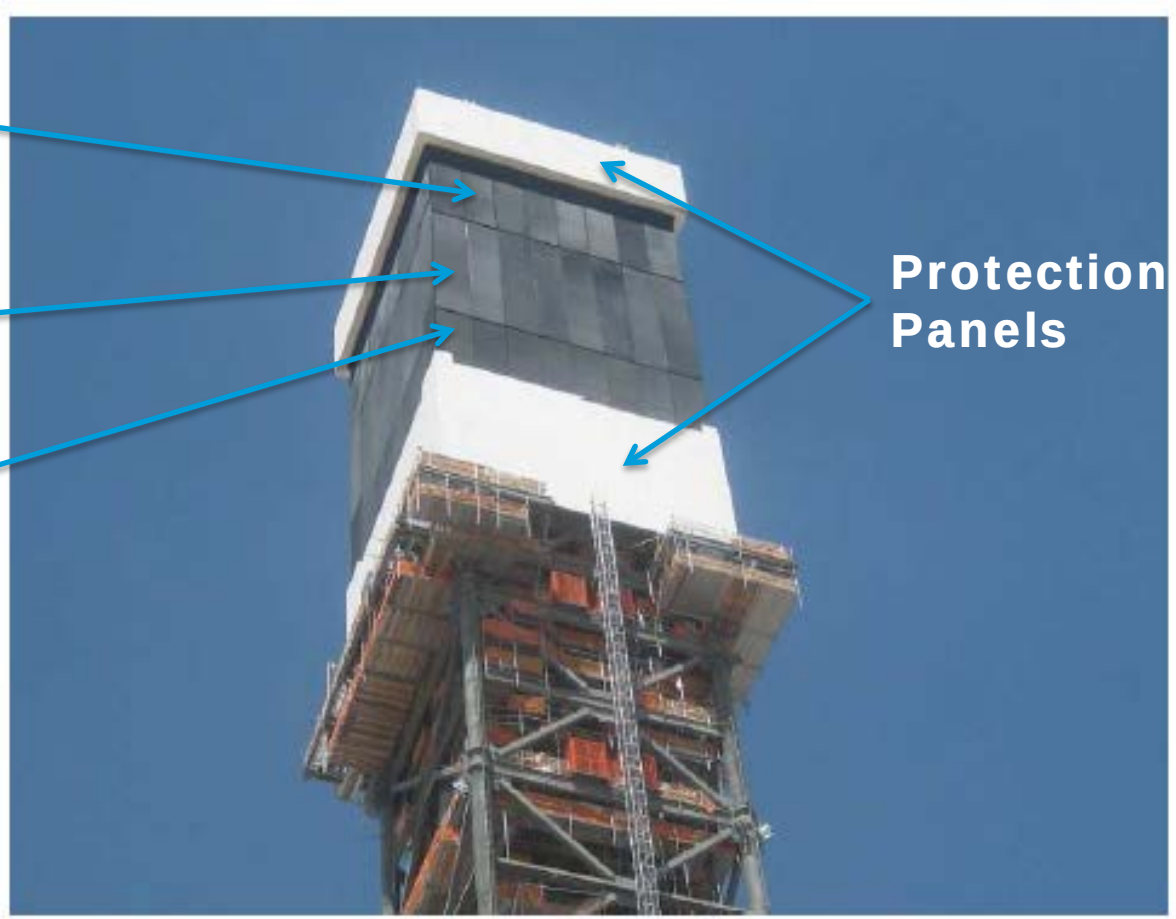
HELIOSTATS
Software-controlled field of mirrors concentrate sunlight on a boiler mounted on a central tower.

Solar Receiving Steam Generator

Boiler

- Steam Design Parameters:
  - Pressure: 2646 psig
  - Temperature: 1013 F
- Boiler Components
  - Evaporator section
  - Super Heat Section
  - Reheat Section
  - Protection Panels

Solar Receiving Steam Generator



Steam Turbine Generator

Turbine

Siemens SST-900

HP and IP Turbine

HP – 7200 RPM | IP/LP – 3600 RPM

Reduction gear box for HP

Generator

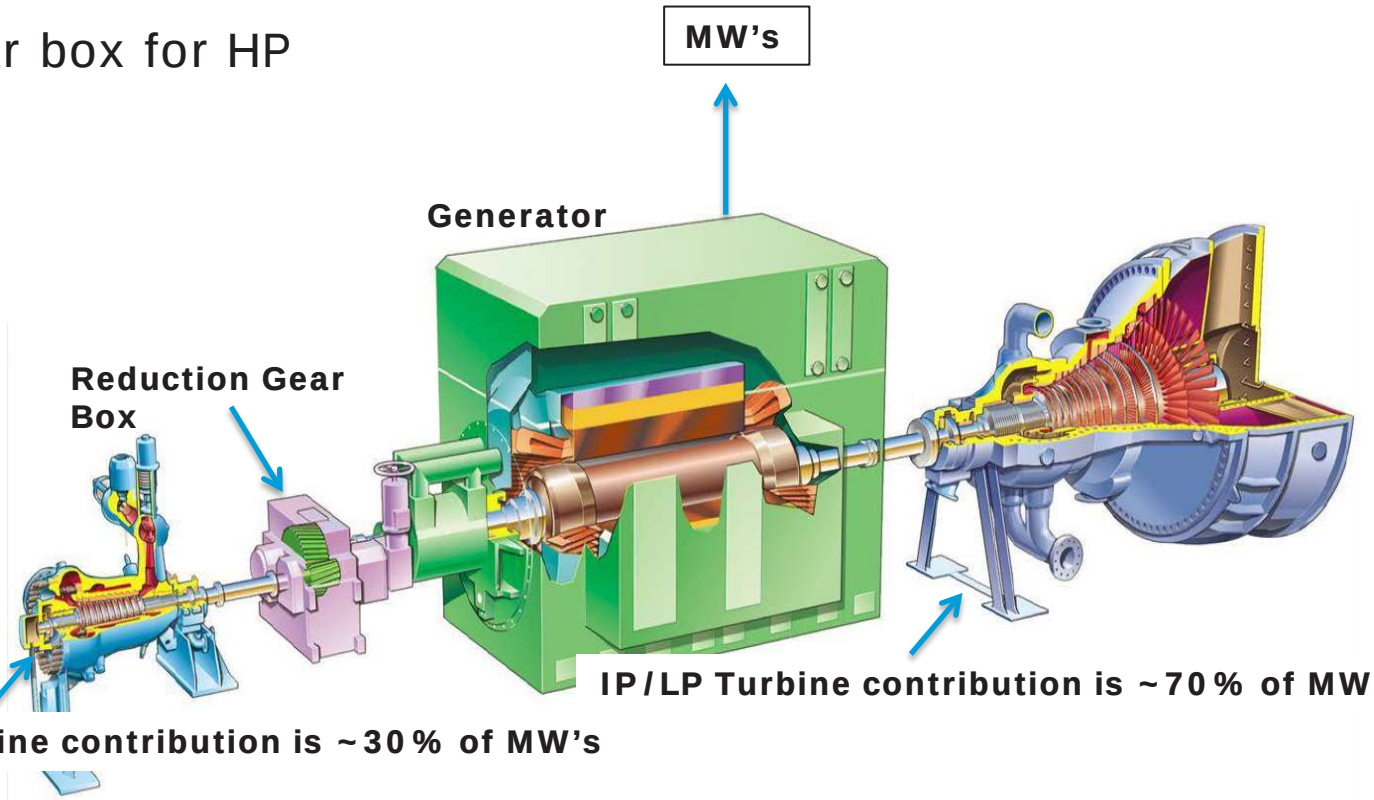
126 / 133MW

3600 RPM

Design

Fast Startup

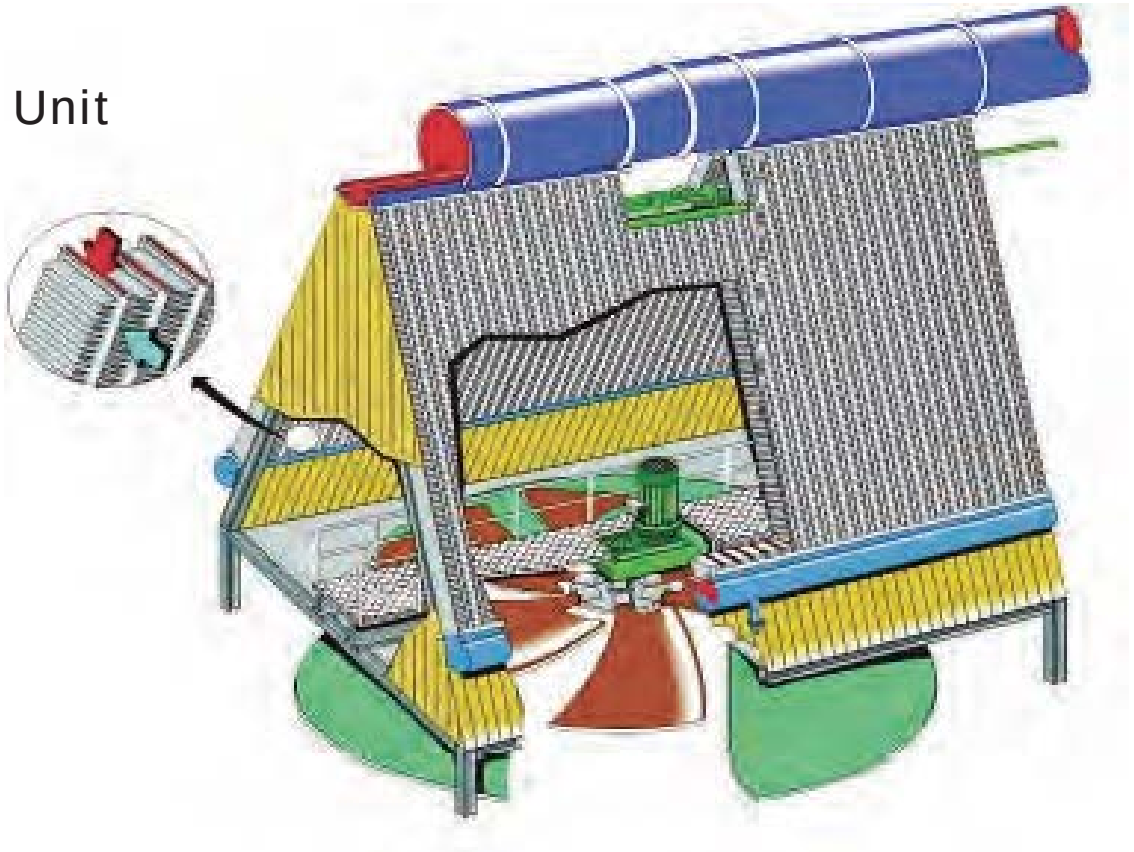
Daily Cycling



Air Cooled Condenser

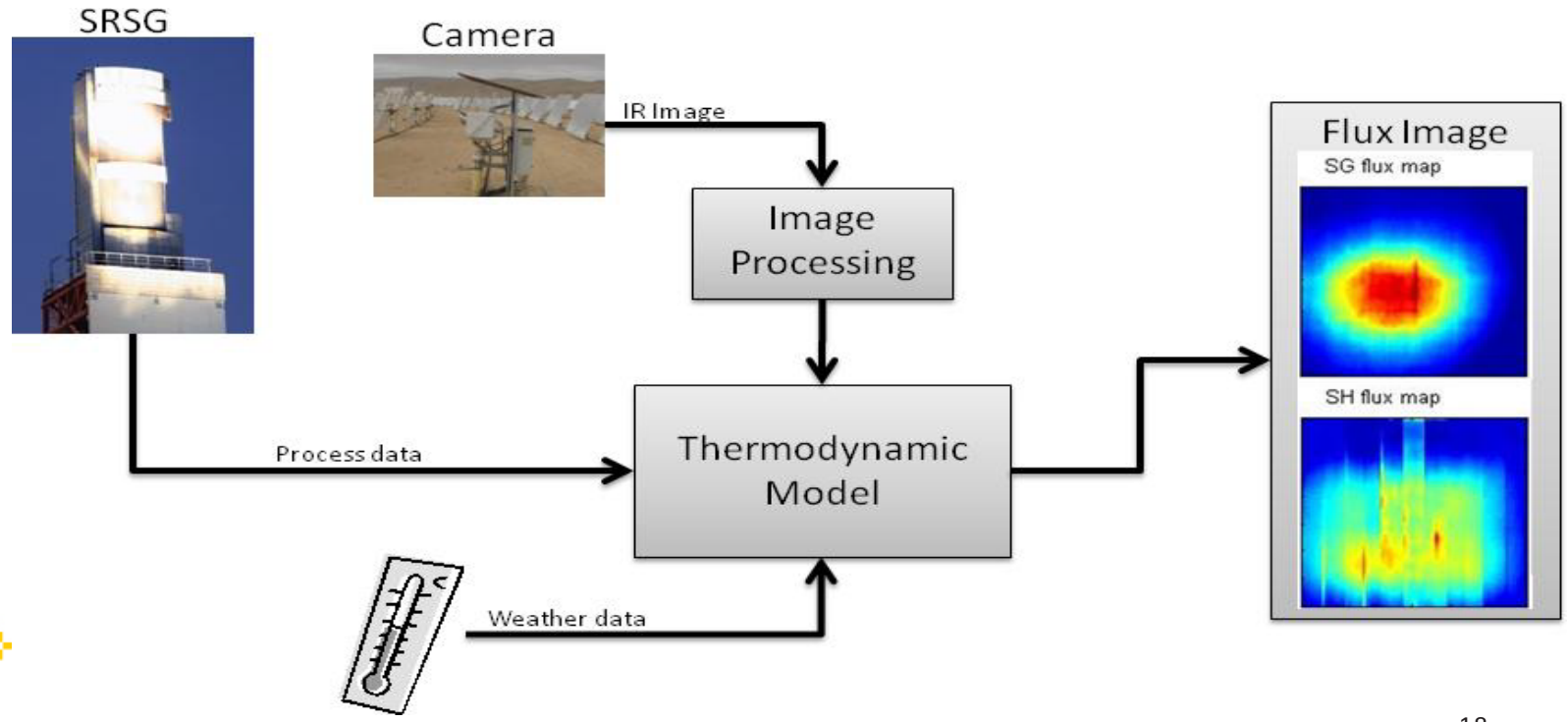
ACC-SPX

- Water Consumption limited to 100 acre-ft / year
- 3 Streets of 5 fans / Unit
- 2 Speed



Solar Field Control System (SFINCS)

- Heliostat desired aiming points calculating to:
- Flux vs Load balancing
- Implement quick flux reduction / defocusing
- Measuring SRSG skin temperature
- Alert on crossing temperature limits



Instrumentation

System Components: Heliostat

- LH-2.2 Heliostat
  - 2 Mirrors/heliostat
  - Metal support structure
  - Dual-axis drives
  - Heliostat controller
- Focuses sun on SRSG
  - Under SFINCS control

About 75 sqft per Mirror
(~size of a single car garage door)

Chemistry Monitoring

Plant 1-3 - STEAM PURITY PERFORMANCE for 5/1/2017												
	Condensate Pump		*Polisher*	*Feedwater*		*SRSG*	*Main Steam*			*RH*	***TOTAL***	*LSL*
unit	DO	CAT Cond	CAT Cond	Specific Cond	DO	Specific Cond	Silica	Sodium	CAT Cond	CAT Cond		
Unit 1	100.00	92.10	100.00	100.00	96.45	100.00	100.00	100.00	100.00	100.00	99.43	10.3
Unit 2	96.39	66.99	100.00	100.00	96.12	97.50	100.00	92.09	100.00	97.92	96.71	12.0
Unit 3	97.76	47.83	99.86	100.00	100.00	100.00	100.00	100.00	99.02	100.00	97.23	11.9

A "Cool Project" – World's Largest CSP

Environmental Benefits

140,000	▪ Typical U.S. homes powered per year
70,000	▪ Cars off the road, per year (avoided emissions equivalent)
12,300,00	▪ Metric tonnes of avoided CO_2 over 30-year life-cycle (363,000 MT/yr)
123,350 (100 AF)	▪ Cubic meters of water used per year (less than 300 U.S. homes)
Less than 1%	▪ Concrete surface impacted. None used with pylons. Low impact construction design.

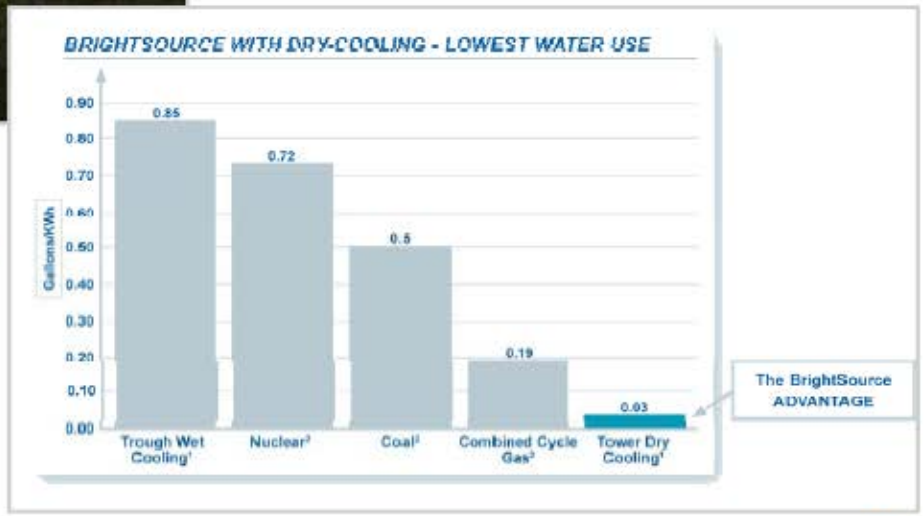
Enough reflective area to cover approximately 600 football fields…enough mirrors to replace all the windows of the Empire State building…54 times

Low Impact Development

- Highly land efficient; 1/3 less land per MWh
- Provides for heliostat placement and flexible plant design to work within natural land contours
- Avoids impacts and costs of extensive land grading and concrete pads

Key design parameters:

- Water Use: dry-cooling, conservation and closed-loop recycling
  - Uses air instead of water to condense steam
  - Uses over 90% less water than CSP using traditional wet-cooling




Sustainability is the ability to endure into the future.

The end ☺
Thank you!