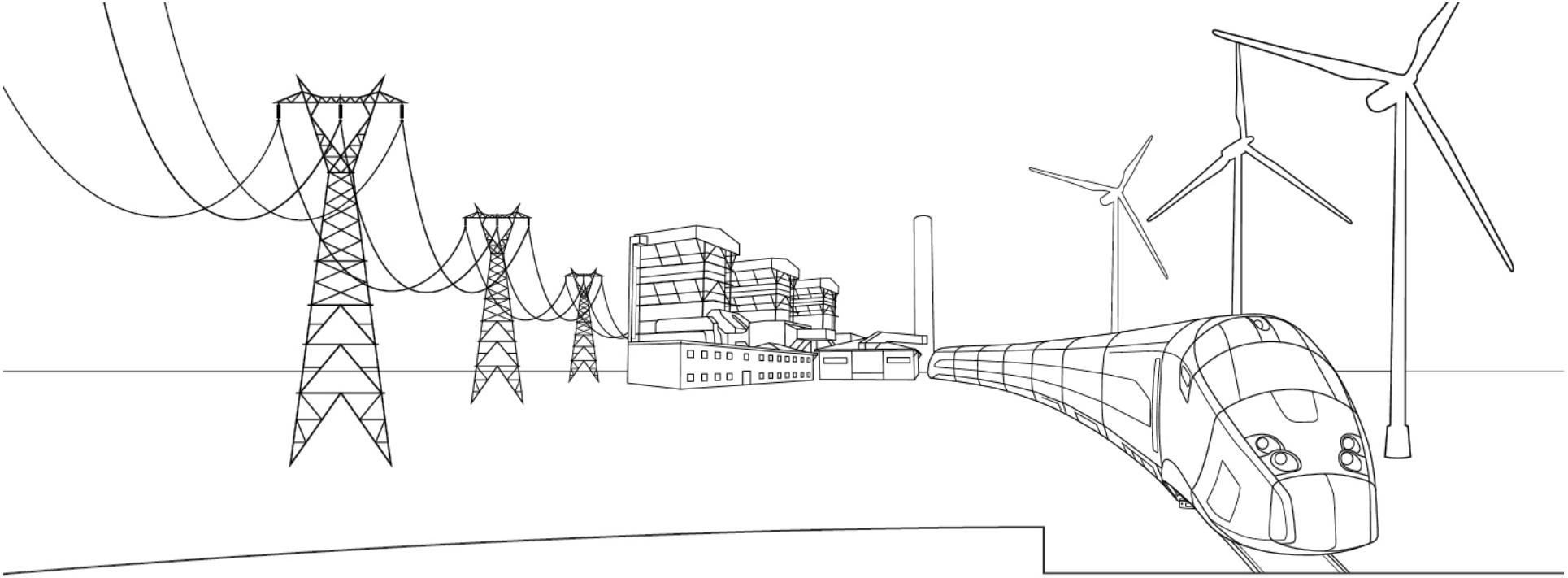


Concentrated Solar Power with Storage

Vipluv Aga, *Alstom Renewable Steam Plant*

IRENA Workshop - New Delhi

December 2014

ALSTOM

Shaping the future

Who We Are
Alstom: Three main activities in four sectors

Equipment & services for power generation

Alstom Thermal Power

Equipment & services for power transmission

Alstom Grid

Alstom Renewable Power

Equipment & services for rail transport

Alstom Transport

ALSTOM

Alstom: more than 30 years of experience in solar thermal

SEGS (California, USA)
SEGS 06, 35 MW ST
SEGS 07, 35 MW ST
SEGS 08, 89 MW ST
SEGS 09, 89 MW ST

1988 - 1990

Ain Beni Mathar ISCC
(Morocco)

GTs & ST

2007

Crescent Dune
(California, USA)

125 MW STG

2011

Ashalim
(Israel)

121 MWe EPC

2014

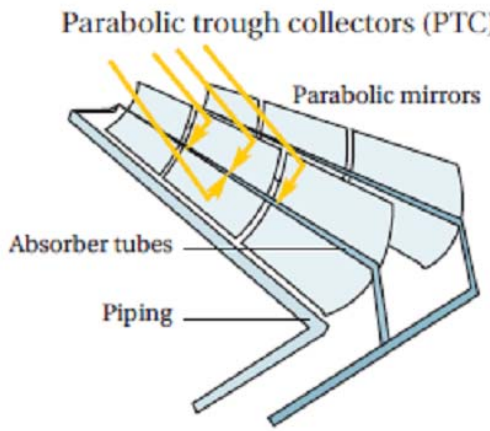
Alstom investment in BrightSource
Strategic Partnership Established

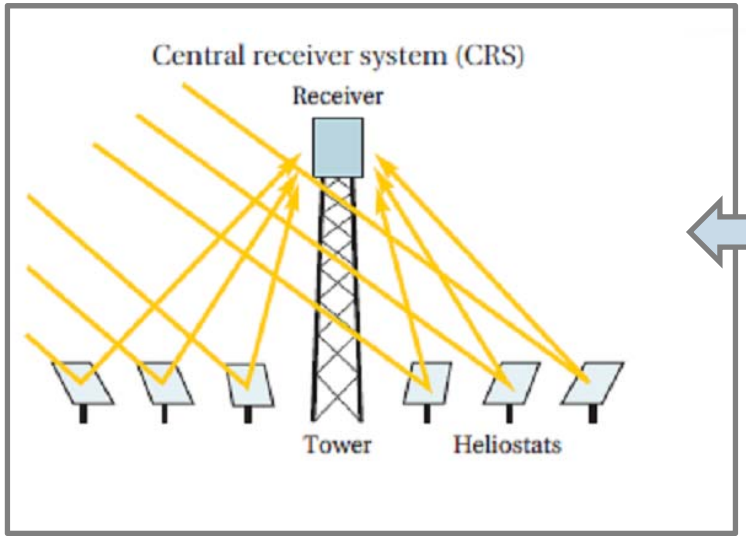
BrightSource

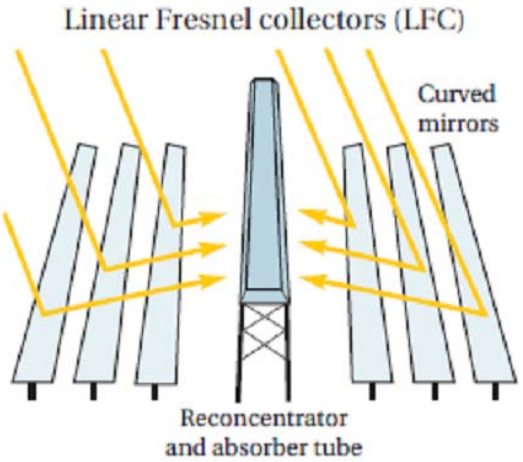
Since 2010

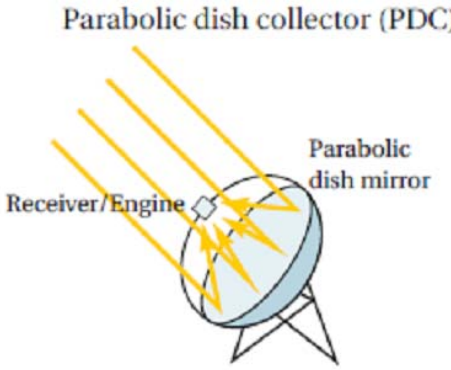
ALSTOM

What is Solar Concentrating Power?









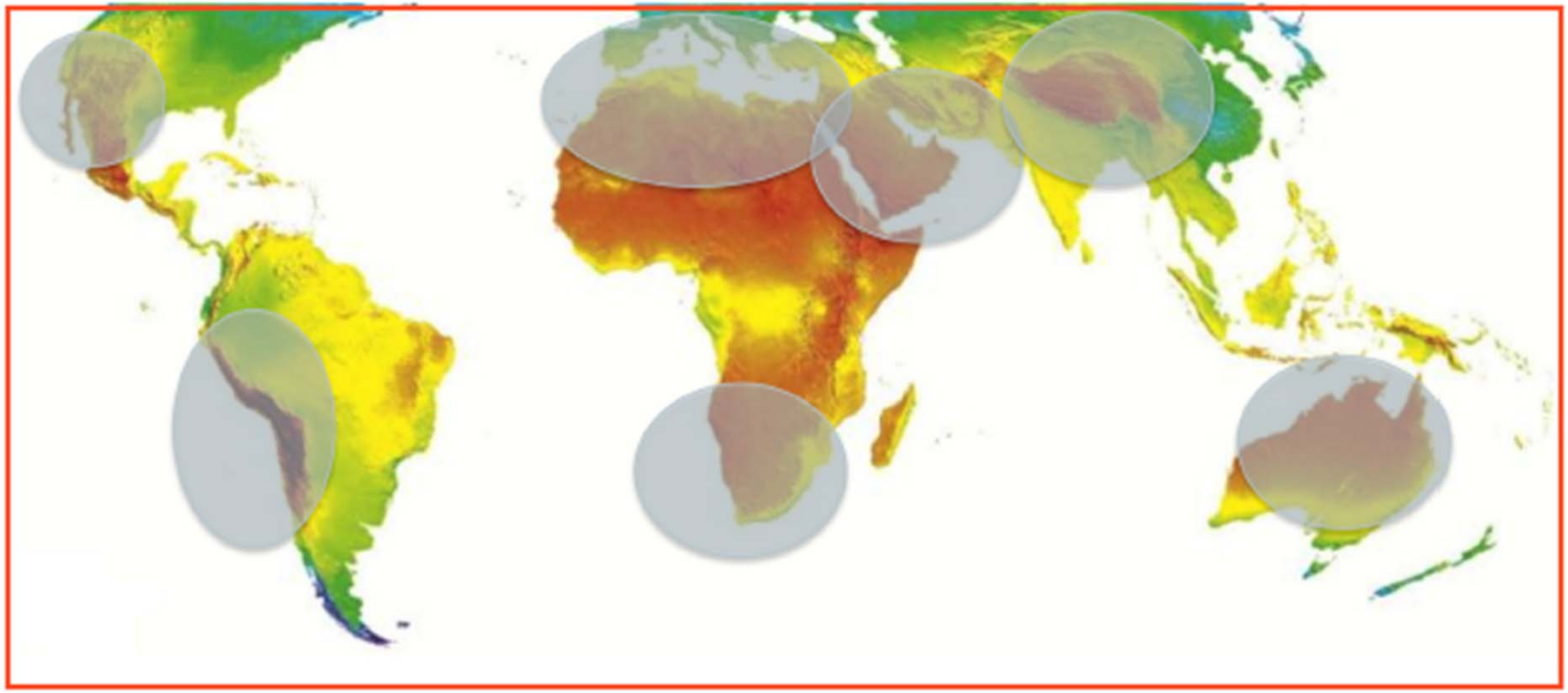
ALSTOM

BrightSource

ALSTOM

Where does CSP work best?

Figure 5.2 - Global markets for CSP in high DNI regions

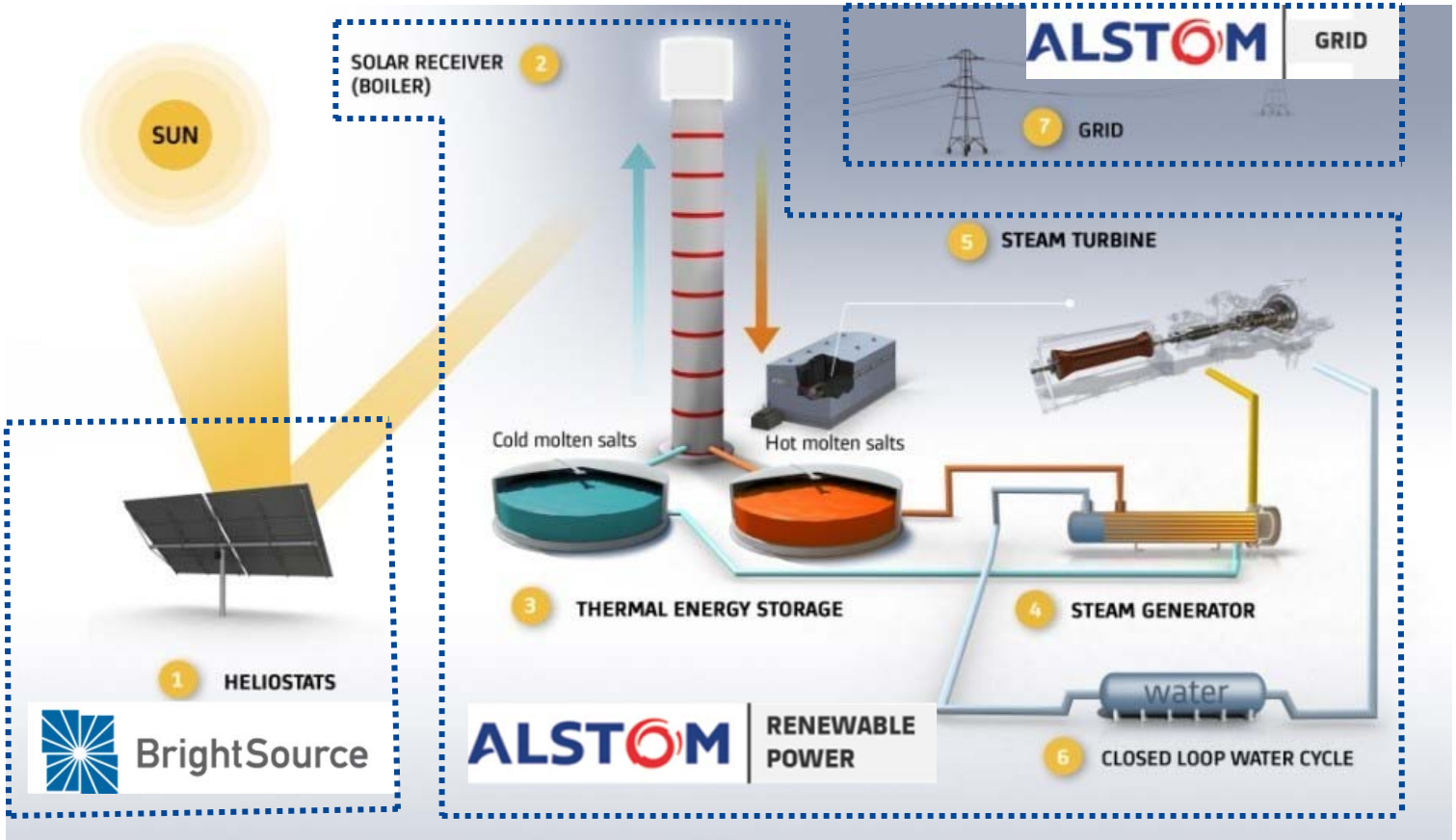


Source: CSP Alliance Technical Report dated September 2014

ALSTOM

Alstom and Brightsource energy partnership

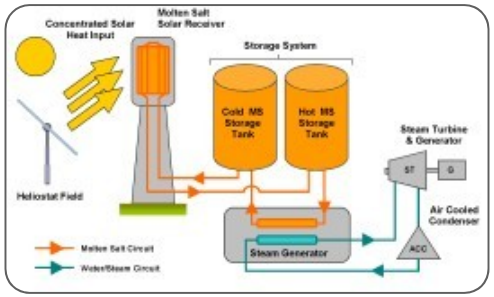
Combining Alstom's extensive experience in the field of turnkey power plants and key power equipment with BrightSource's LPT solar thermal technology



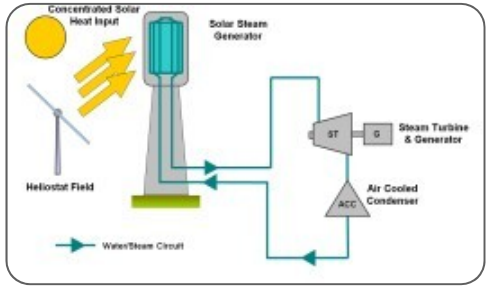
BrightSource ALSTOM

Offering Concentrated Solar Power

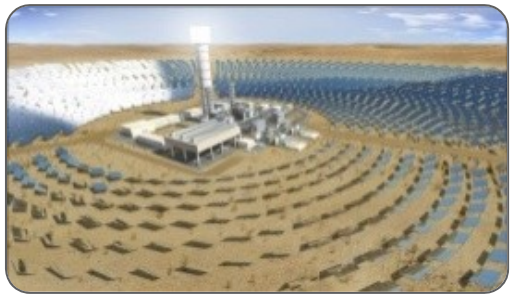
1. **Molten salt solar tower** plant and thermal energy storage for capacity above 50MWe



2. **Direct steam solar tower** plant for 120-250MWe with/without thermal energy storage



3. **Integrated Solar Combined Cycle** for 50Hz/ 60Hz with possible generation by solar only (GT shut down) – high cycle efficiency

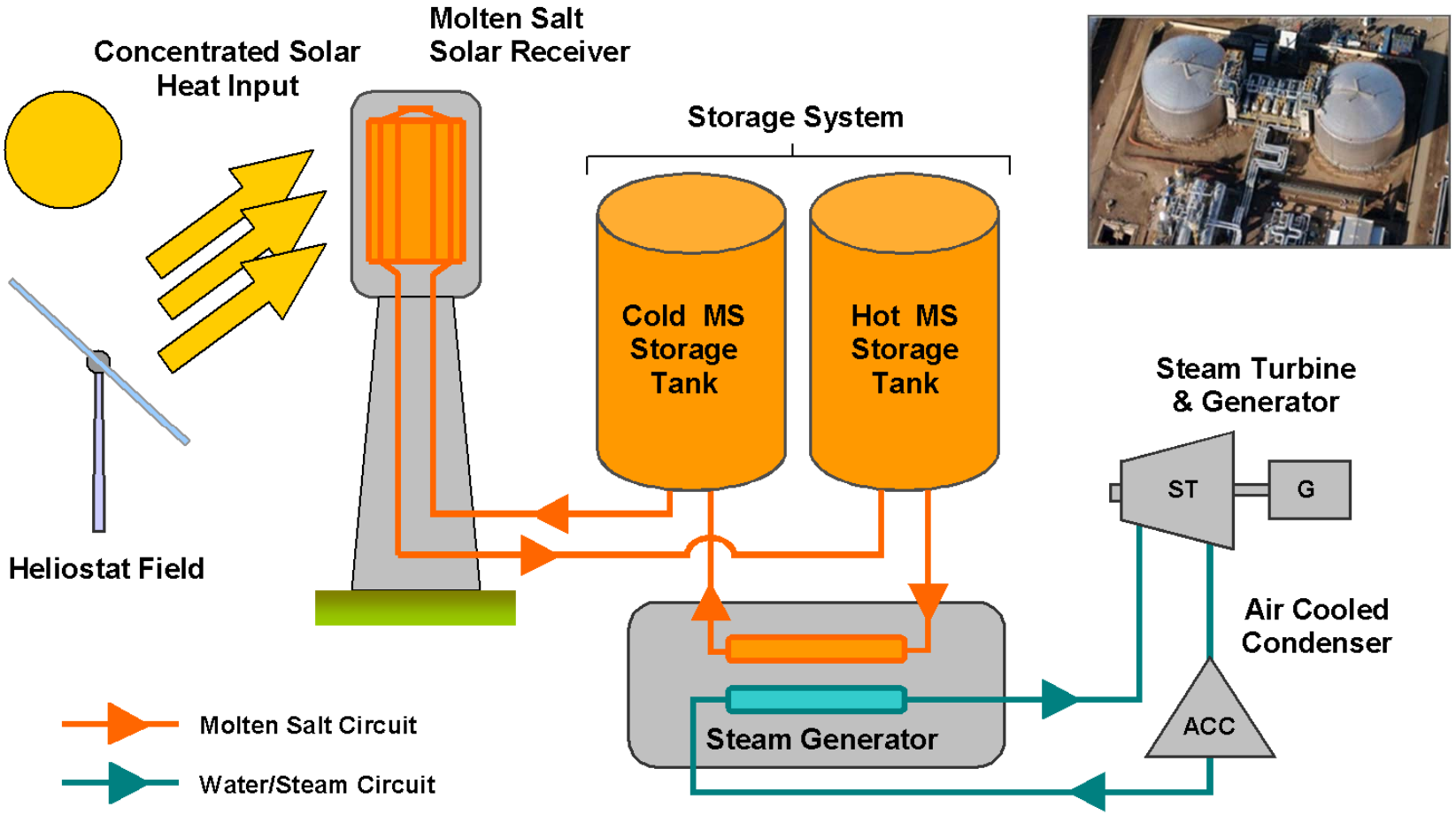


4. **Coal/Solar hybrid** – 50Hz/60Hz high cycle efficiency on coal LHV, lower CO_2 emissions

Turnkey solution with in-house components

ALSTOM

Solar Power Tower With Storage



Classic, Proven, Two-Tank Molten Salt Power Tower Technology

BrightSource ALSTOM

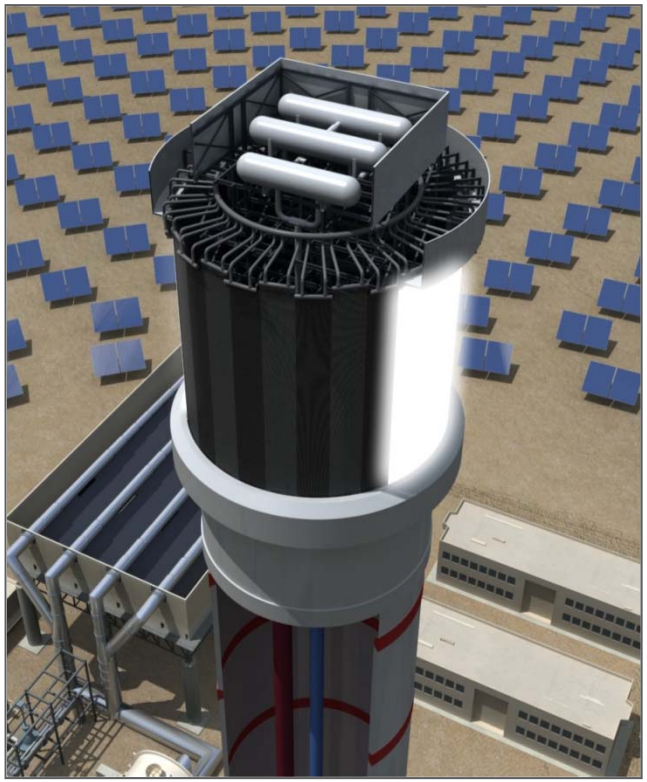
Heliostats: intelligent and precise

System delivers beam accuracy in excess of one mile

- Heliostats individually positioned in field to optimize annual plant output
- Account for real time weather, sun location, and wind
- Heliostats “communicate” with each other to optimize radiation collection and solar receiver heat balance
- Two flat glass mirrors (2.3m x 3.3m) mounted on a single pylon equipped with a computer-controlled drive system

BrightSource ALSTOM

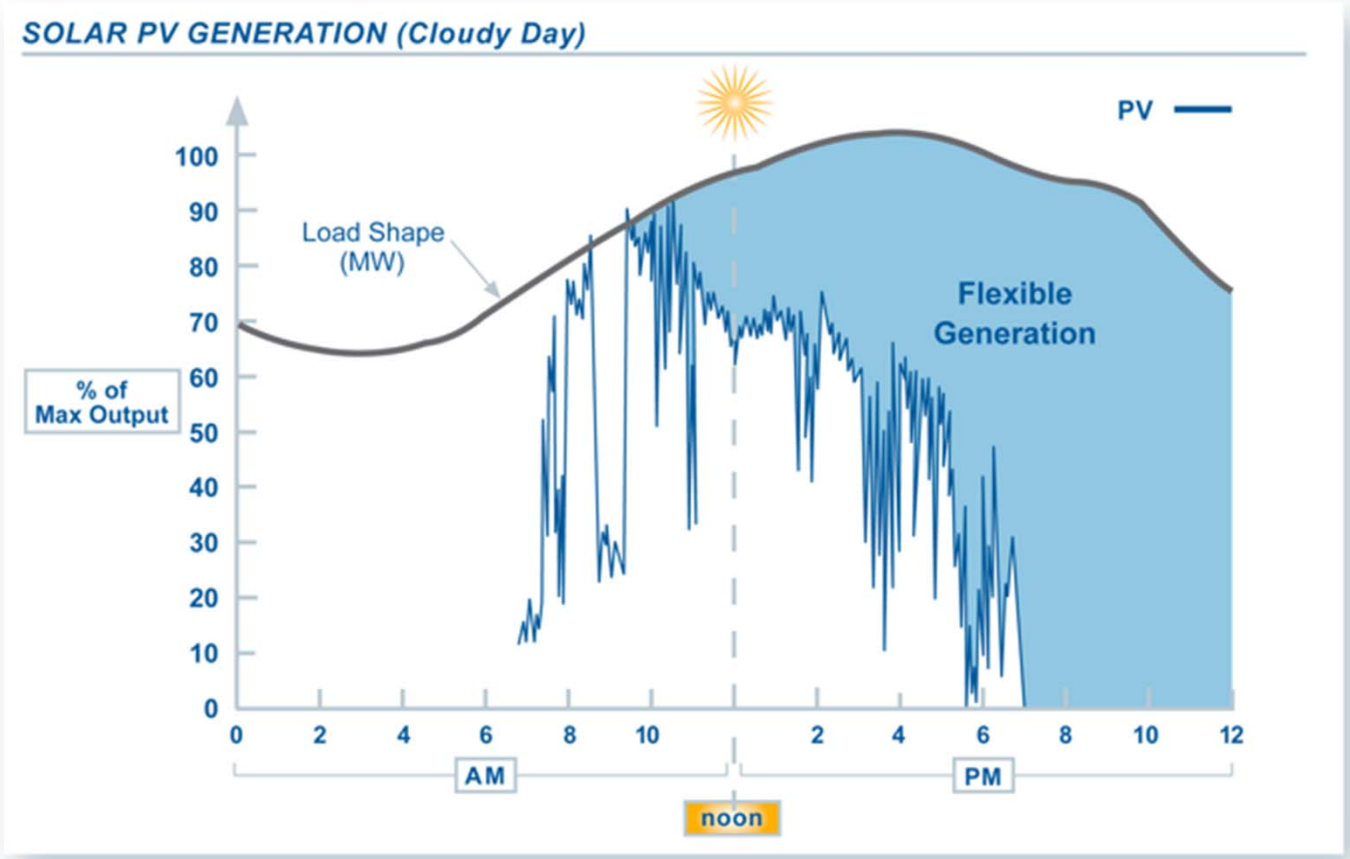
Molten Salt Central Receiver (MSCR)



- Maximum rating of approximately 750MWth capacity
- Proprietary receiver coatings to maximize solar energy absorption
- Low pressure operation (atmospheric vents)
- Fast start-up to minimize daily energy losses

BrightSource ALSTOM

Output variability impacts grid reliability and increases costs …



PV Output Variability

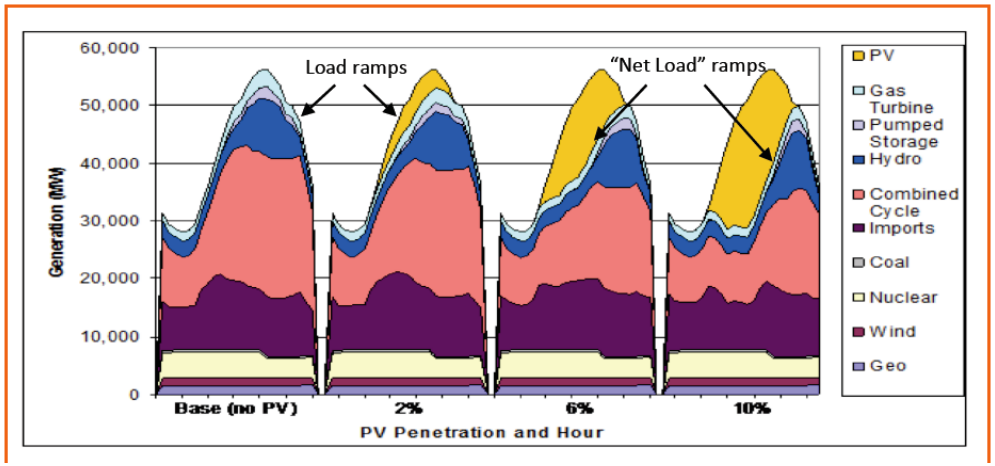
… Requiring additional flexible generation to maintain reliability

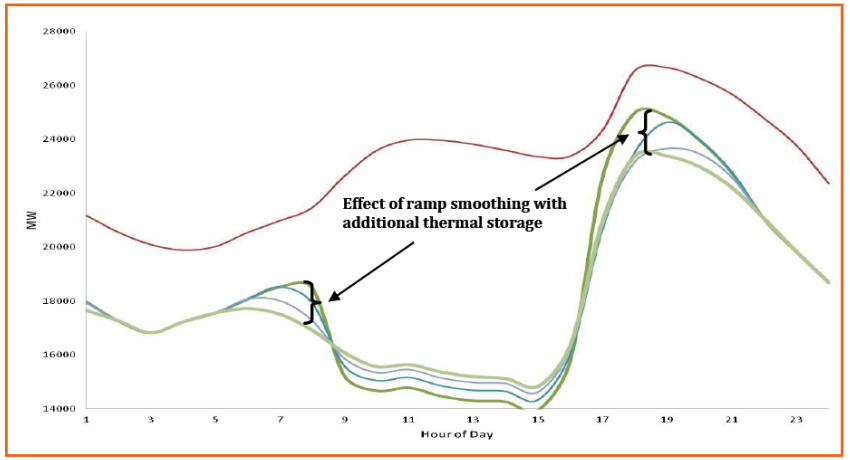
Chart Source: NERC – Accommodating High Levels of Variable Generation

Load shape source: California's Electricity System Supply and Demand Overview, presentation by Jeffrey Byron, Commissioner, State Energy Resources Conservation and Development Commission (energy commission), to the California State Assembly Utilities and Commerce Committee, Informational Hearing, March 29, 2007.

BrightSource ALSTOM

CSP value proposition: dispatchability





Source: 2014: CSP Alliance The economic and reliability benefity of CSP with thermal energy storage

- For utility scale – high DNI areas, CSP to be exploited for its cheaper and proven storage capability
  - Equivalent marginal cost of thermal storage ~ 20-30 $/kWh (min 25-30 yr lifetime) compared to 400-800 $/kWh from batteries
- CSP to suppport supply and demand even with strong ramps and supply demand-mismatch from PV

CSP with storage is a dispatchable, grid-code compliant, renewable source that helps to manage large PV penetration

ALSTOM

CSP value proposition: energy benefits

Figure 7-2: Energy benefits ($/MWh) of solar resources from selected studies of increasing solar penetration

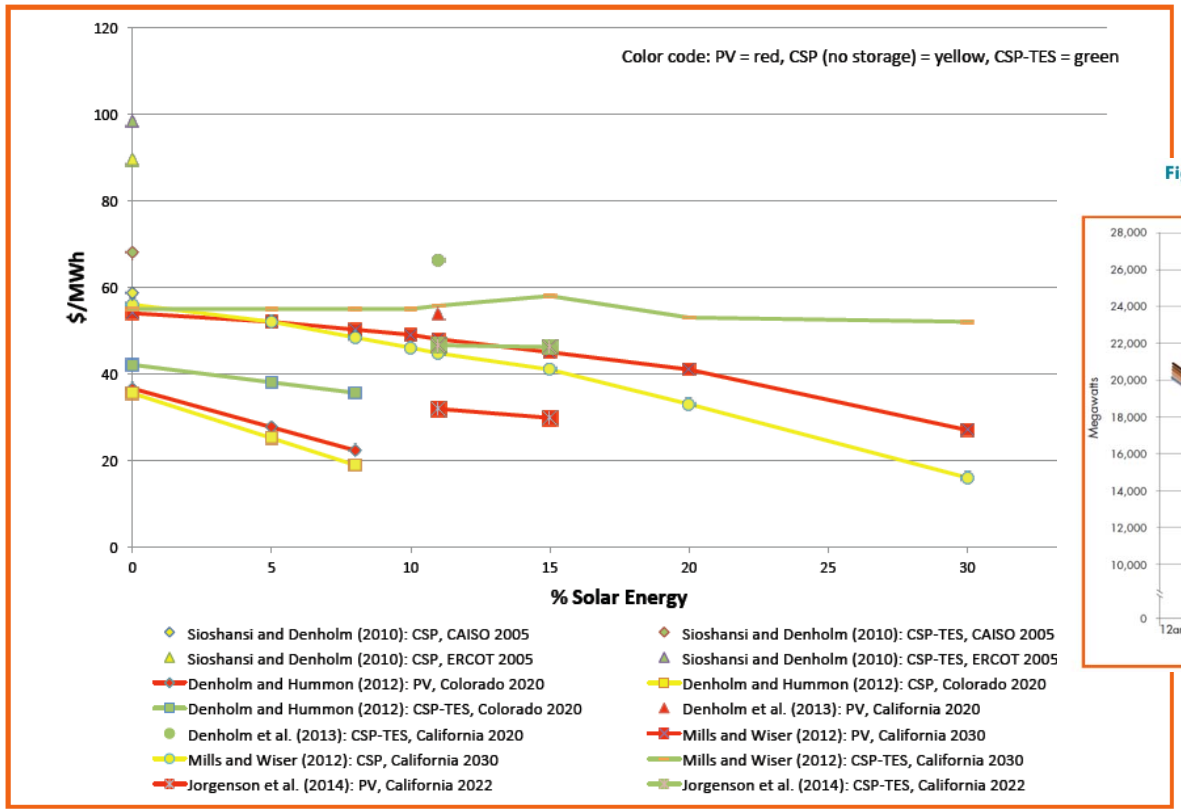
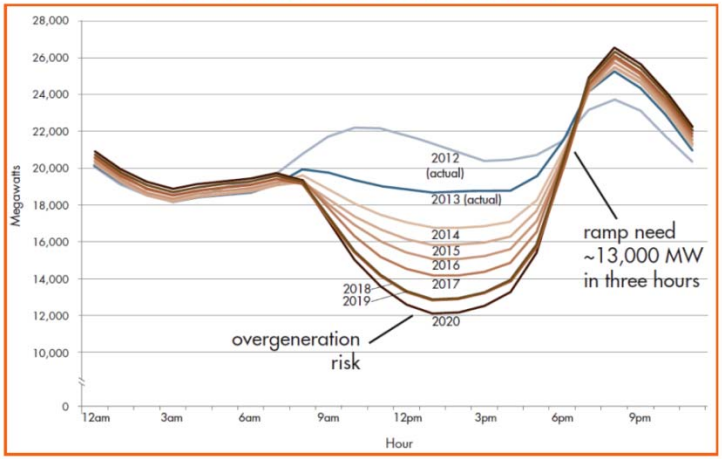


Figure 6-3: Evolution of Hourly Net Load (Wind + Solar) Ramps in the California ISO for a Spring Day, 2012-2020

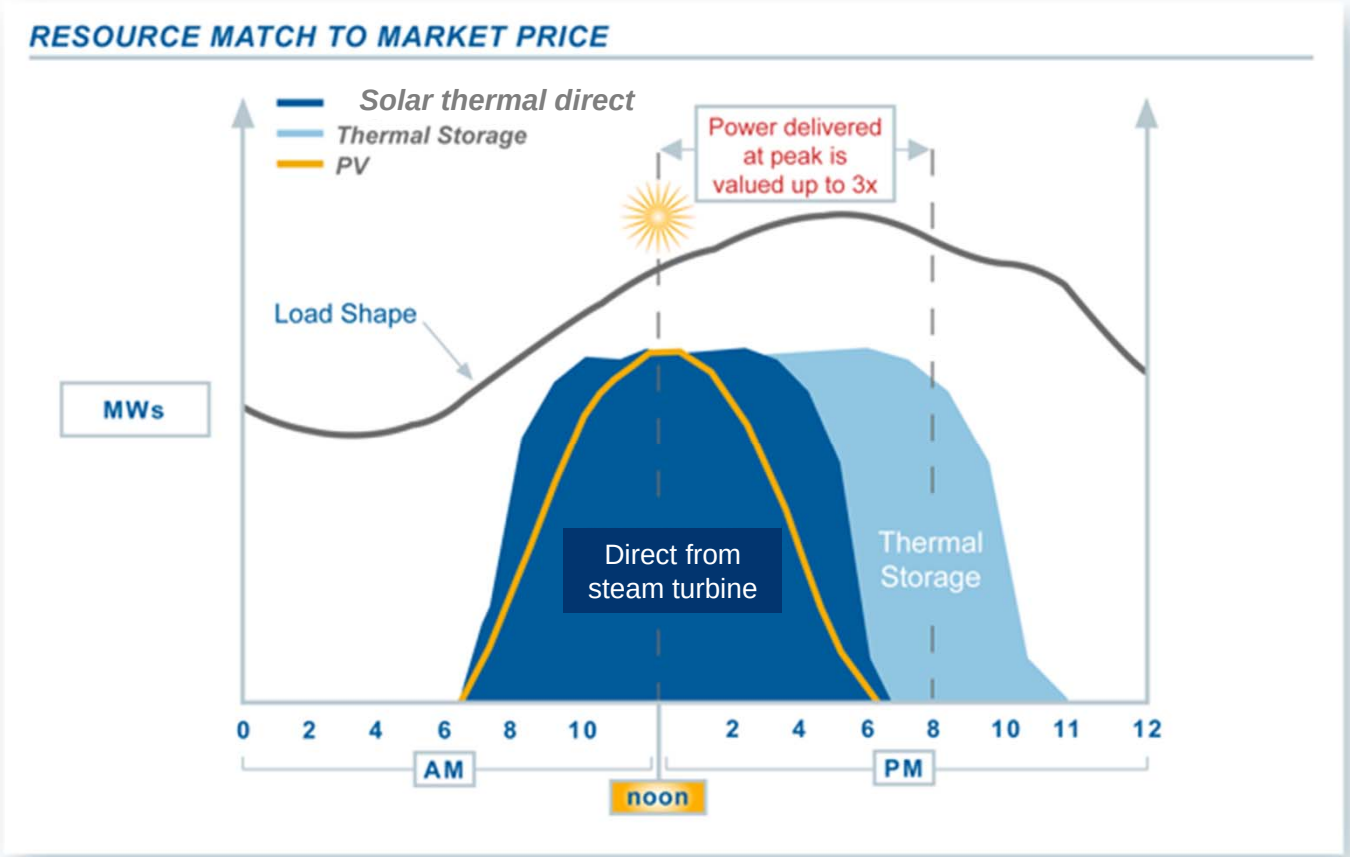


Source: 2014: CSP Alliance The economic and reliability benefity of CSP with thermal energy storage

CSP produces savings from **not needing** additional reserves to manage intermittent generation ramps

ALSTOM

Net system cost is used by utilities to evaluate cost competitiveness



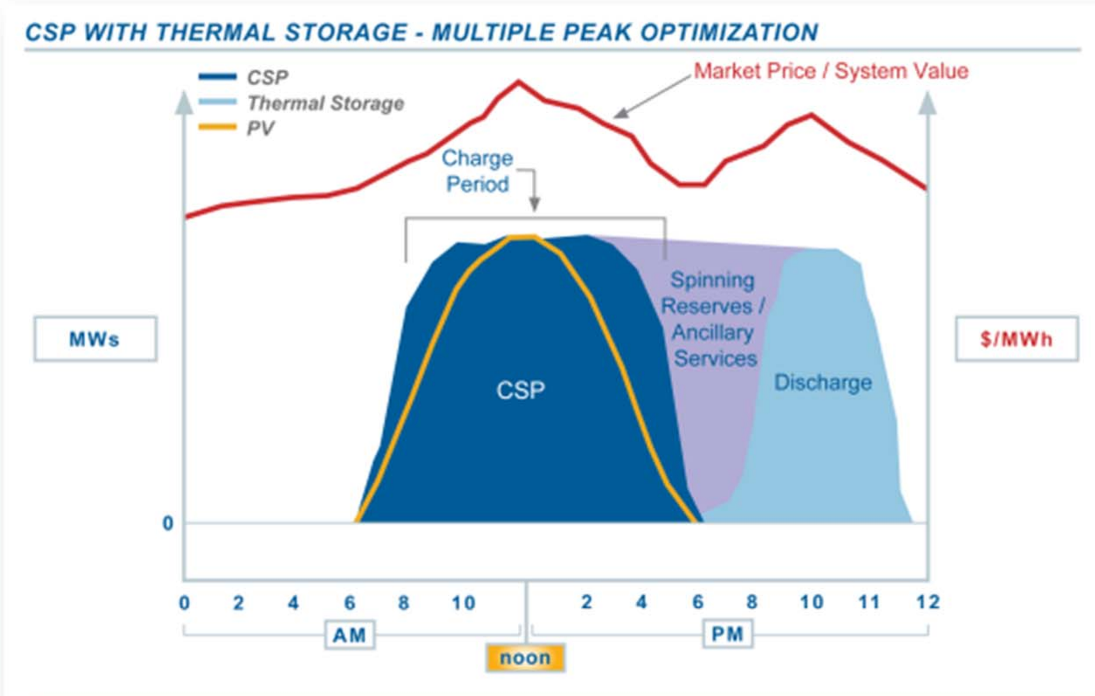
Energy storage increases asset utilization and transforms solar thermal into a high-value, flexible resource

Note: CA utility time-of-use factors based on PG&E and SCE data
Load shape source: California's Electricity System Supply and Demand Overview, presentation by Jeffrey Byron, Commissioner, State Energy Resources Conservation and Development Commission (energy commission), to the California State Assembly Utilities and Commerce Committee, Informational Hearing, March 29, 2007.
Production output of PV and BrightSource Power Tower are illustrative. Not drawn to scale with load shape curve

BrightSource ALSTOM

Integrating Storage Transforms a Solar Thermal Plant into a High-value, Flexible Resource

LCOE + INTEGRATION COSTS − **ENERGY VALUE** *EXAMPLE 2* − CAPACITY VALUE = NET SYSTEM COST



Storage is discharged when most economic to dispatch the power plant

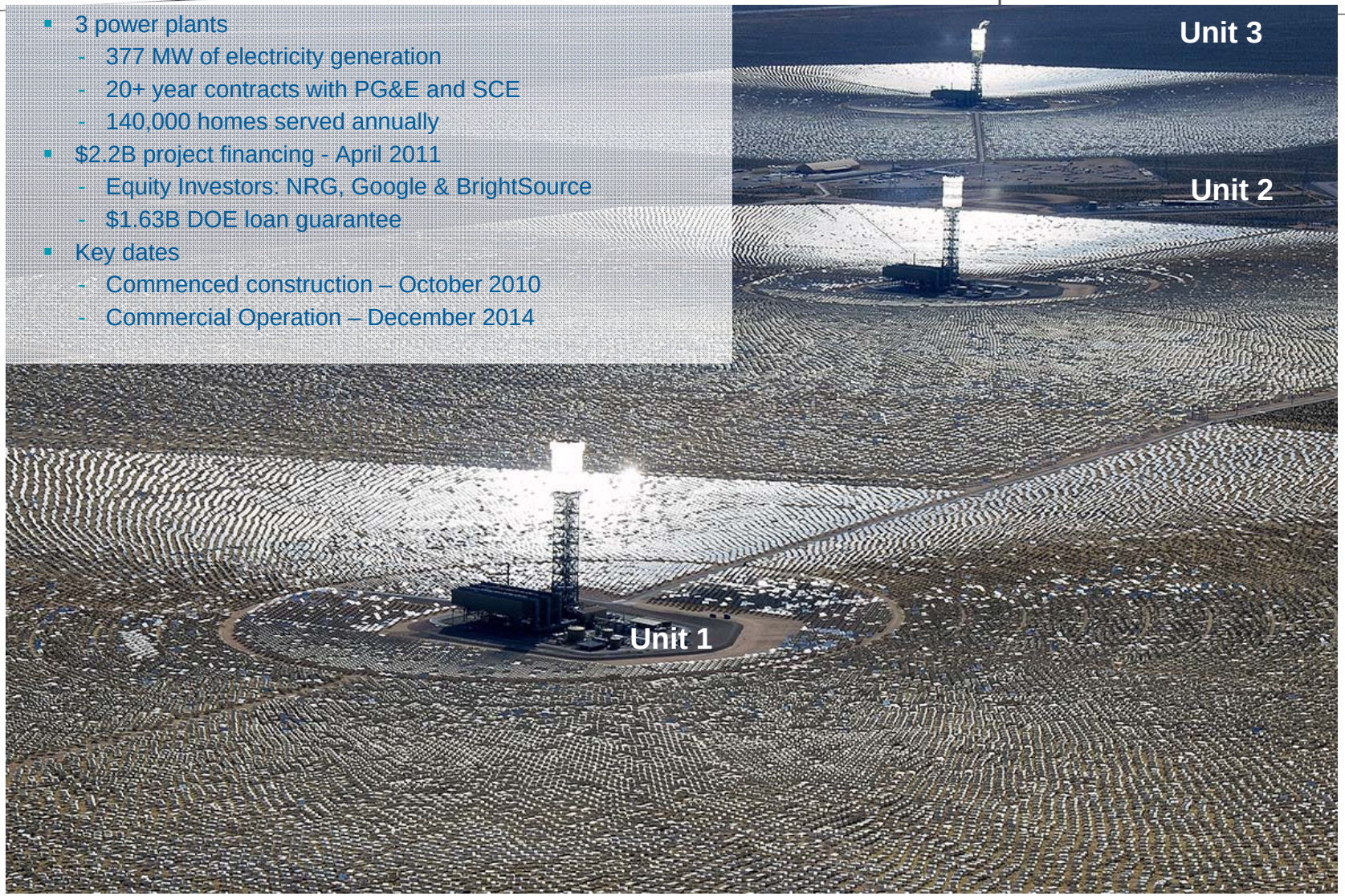
Energy storage enables optimization of production profile against market prices and providing all grid services like conventional plants

Production output of PV and CSP are illustrative. Market Price / System Value are representative, not actual, prices.

ALSTOM

Ivanpah: world's largest solar thermal project

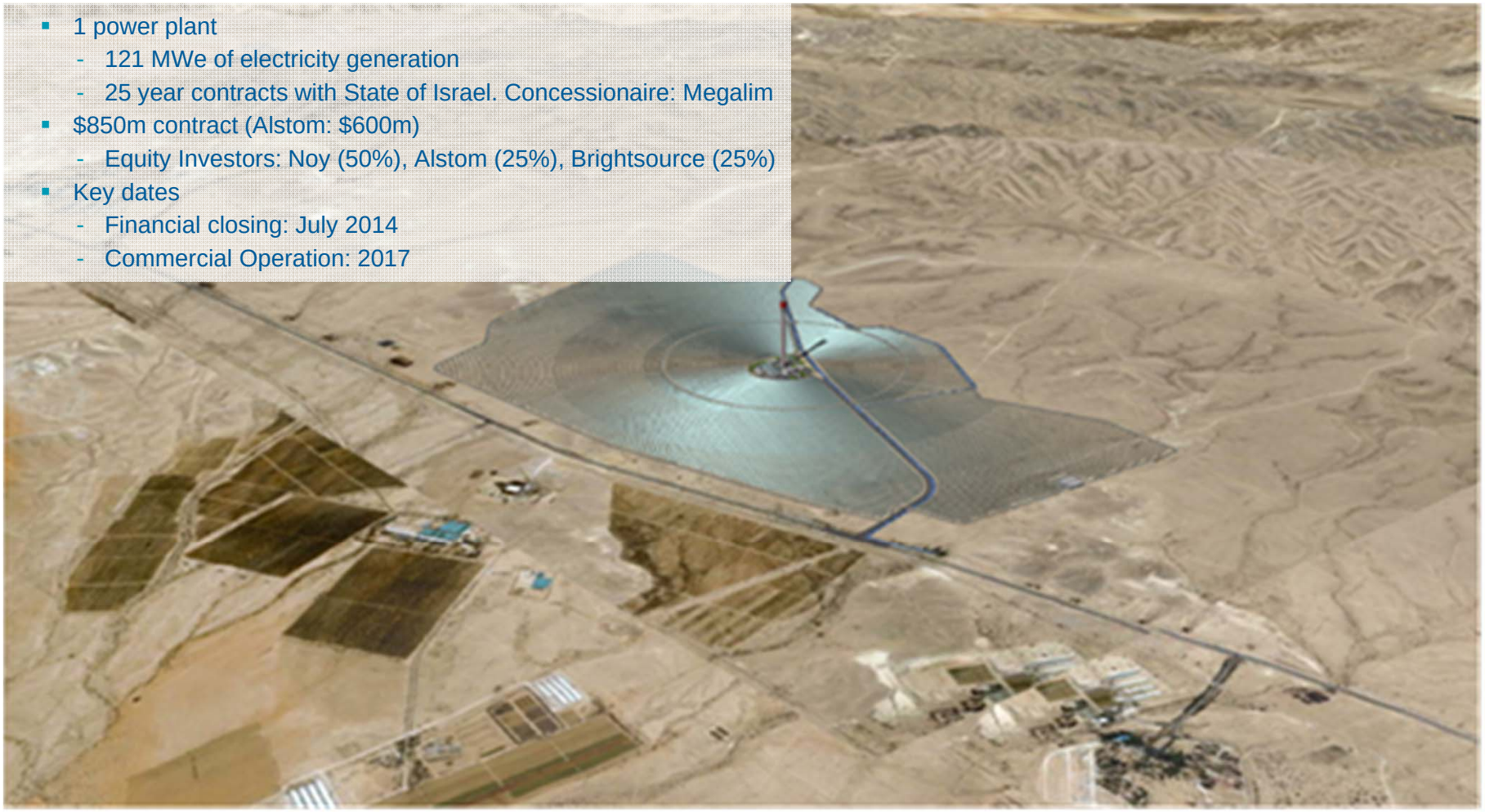
- 3 power plants
  - 377 MW of electricity generation
  - 20+ year contracts with PG&E and SCE
  - 140,000 homes served annually
- $2.2B project financing - April 2011
  - Equity Investors: NRG, Google & BrightSource
  - $1.63B DOE loan guarantee
- Key dates
  - Commenced construction – October 2010
  - Commercial Operation – December 2014



ALSTOM

Ashalim thermal solar power station

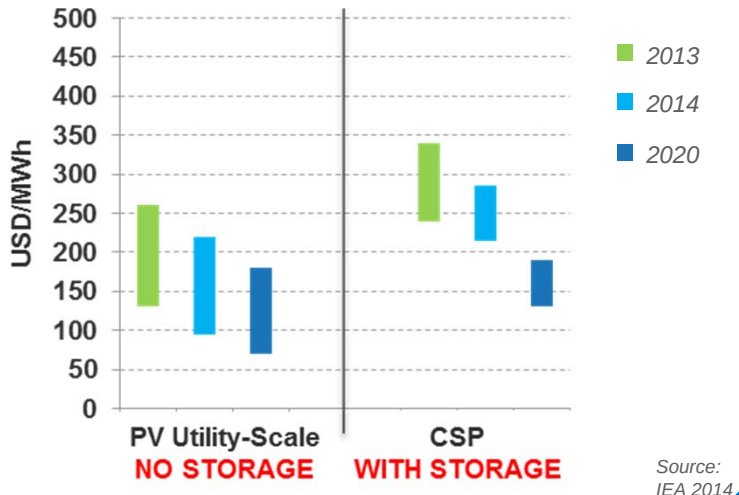
- 1 power plant
  - 121 MWe of electricity generation
  - 25 year contracts with State of Israel. Concessionaire: Megalim
- $850m contract (Alstom: $600m)
  - Equity Investors: Noy (50%), Alstom (25%), Brightsource (25%)
- Key dates
  - Financial closing: July 2014
  - Commercial Operation: 2017



LCOE comparison – real projects

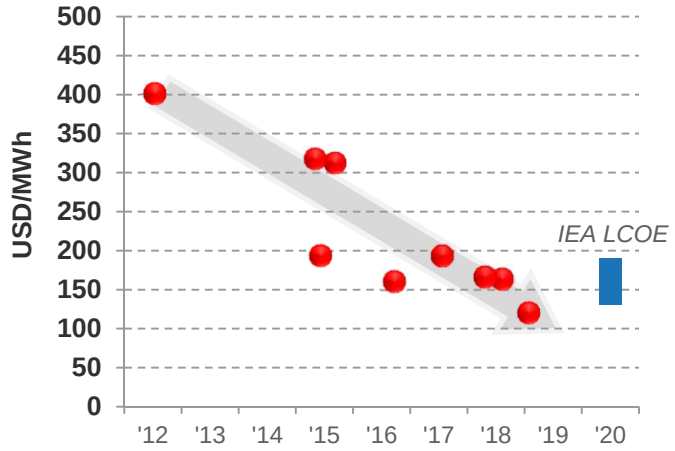
Compare PV (intermittent solar) to CSP + storage (grid-friendly solar)!

LCOE benchmarks do not reflect the true economic value that CSP provides the grid...



Source: IEA 2014

...but CSP tariffs are continuously decreasing over the years for dispatchable solar generation anyways

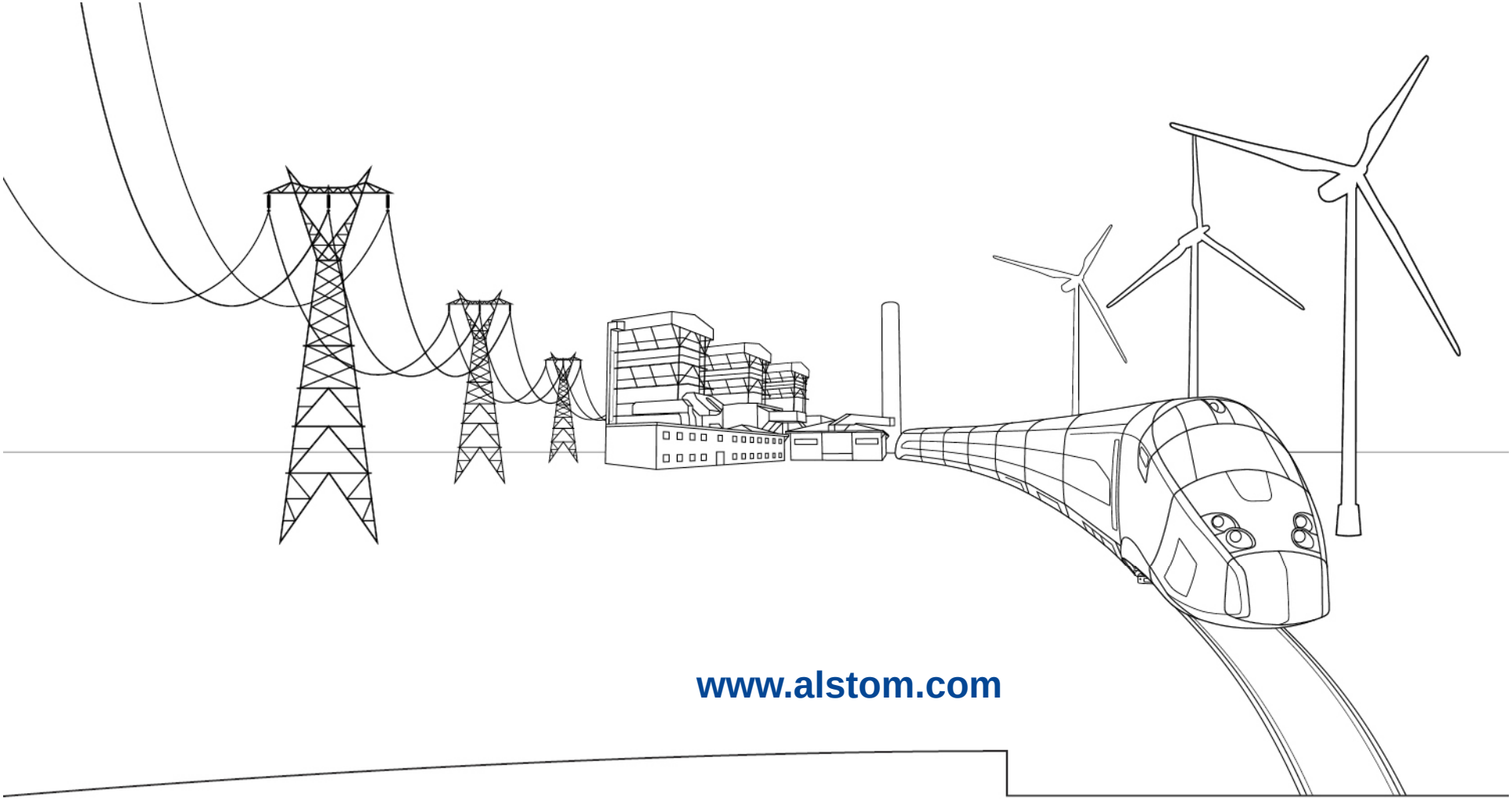


publicly known CSP+storage PPA in USD / MWh vs Commisioning years
Note: chart displays different technologies / sizes / storage durations / countries

- For utility scale – high DNI areas, CSP should be exploited for its cheaper and proven storage capability
- CSP with energy storage helps to match supply and demand
- CSP with energy storage allows even more PV to be integrated in the network

A renewable generator that already meets all grid codes

ALSTOM



www.alstom.com

ALSTOM

Shaping the future