Concentrated Solar Hot Air Turbine Power Generation System

December, 2010

MITSUBISHI HEAVY INDUSTRIES, LTD.

MHI CSR*1 Action Guidelines

*1: Corporate Social Responsibility

MITSUBISHI HEAVY INDUSTRIES, LTD.

In order to ensure future for the Earth, we establish and maintain;

Close ties with the Earth

Safeguard an abundantly green Earth through environmental technologies and environmental awareness;

Close ties with Society

Built a relationship of trust with society through proactive participation in society and trustworthy actions;

A bridge to the next generation

Contribute to the cultivation of human resources who can shoulder responsibility in the next generation through technologies that can realize dreams.

→ Concentrated Solar Power is one of the promising measures to realize all the above company missions.

CSP strategic policy

1. Low cost power generation

Newly developed system must be economically meaningful without financial incentives

2. Environmentally friendly

Zero CO2, No need of cooling water

3. Flexible output for various types of demand

Base system : no fuel and utilize only solar energy
Option : with combustor to generate power for 24 hours

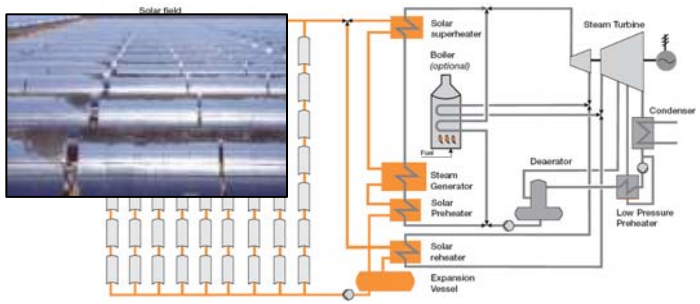
4. Global business deployment with oversea partners

Unlike PV whose core components must be manufactured in high-tech factory, there are large production area for which oversea partners are necessary to minimize the erection cost.

Current Available Technologies (by Other Companies)

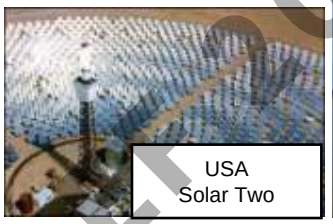
"Concentrated solar power" is a promising technology for large scaled renewable power stations especially in "Sunbelt" area.
It is attractive for summer peak demand as saving the cost for existing power equipment as well as reducing CO2 emission.
Several kinds of systems have been developed as shown below.

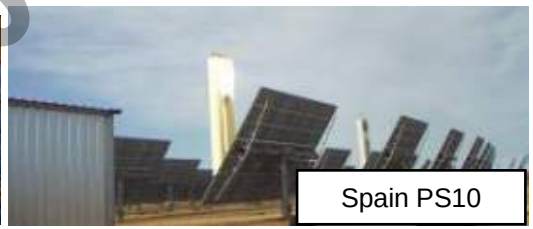
① Trough type (Steam Tubine)



・Spain, USA（SEGS:350MW）

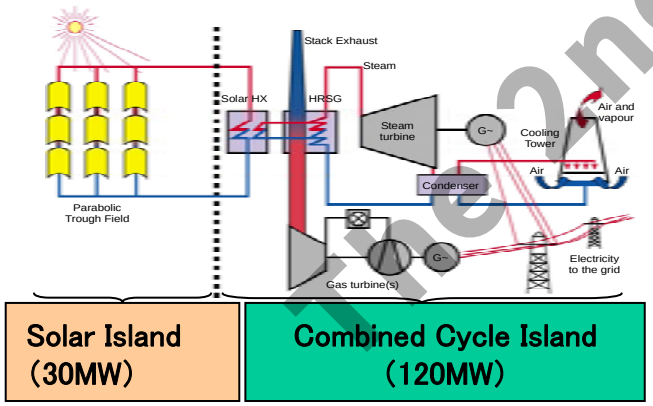
② Tower Type (Steam Turbine)





・USA California Solar Two （10MW）
・Spain PS10（11MW）

③ GTCC Hybrid

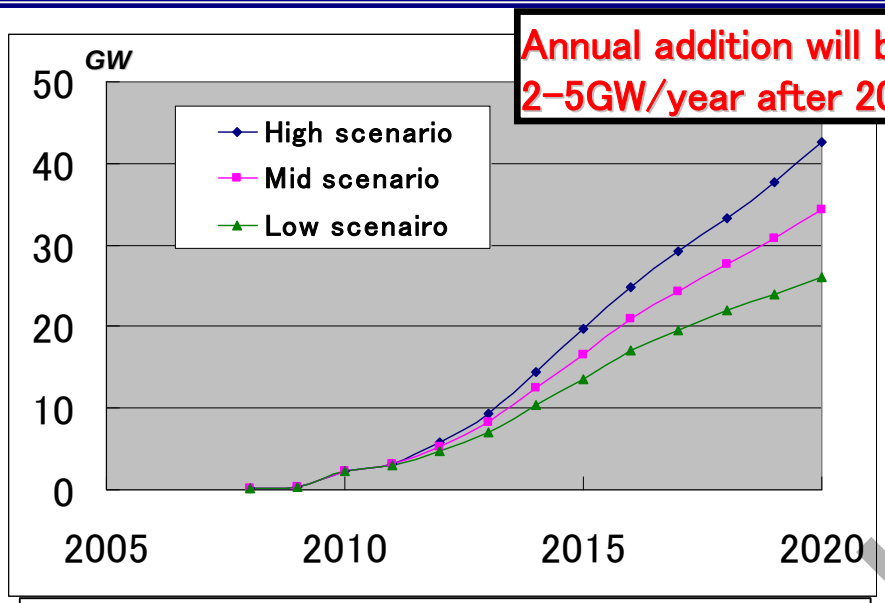


・Egypt／Kuraymat
・Italy（ENEL) Archimede 5MW (July 2010)

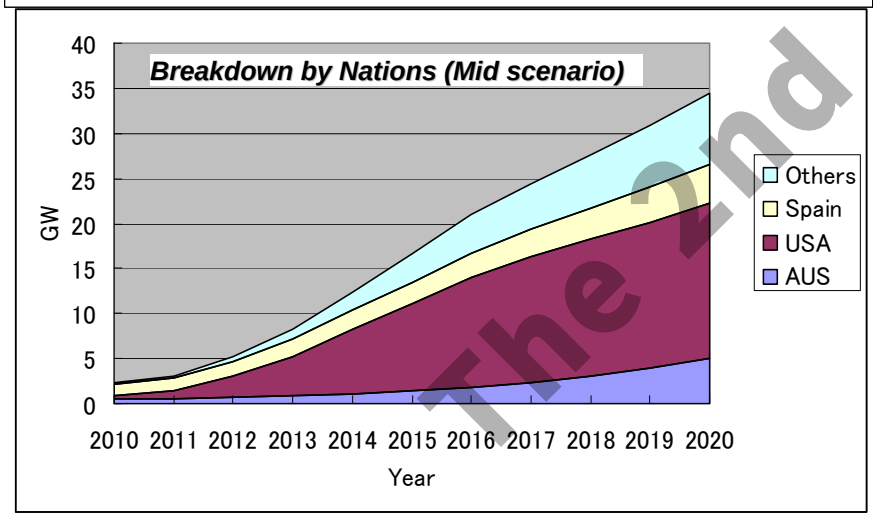
④ Dish Stiring Type

・USA California Vanguard 25kw
（Stirling Energy Systems）

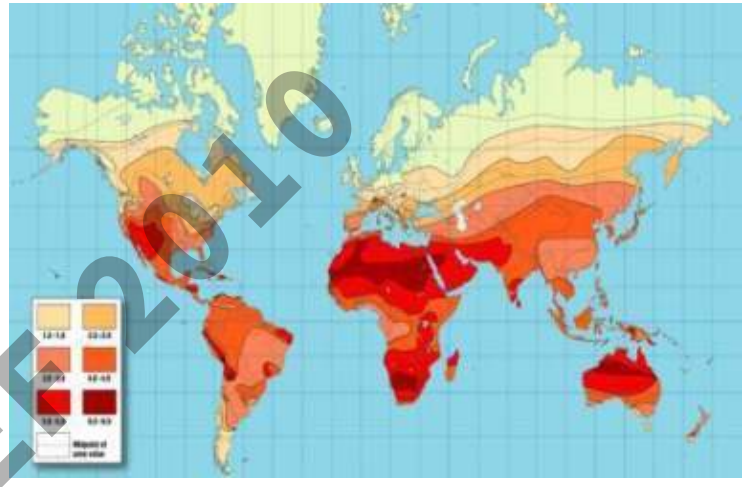
Market Analysis & Energy Resources



Annual addition will be 2-5GW/year after 2014



Global cumulative CSP (GW) by New Energy Finance (September 2009)



Example of the announcement

- **South Africa：500MW/year**
  （by SA Gov. @Oct.2009 World Bank conference）
- **Morocco：200MW/year**
  (by Moroccan Gov. Sep. @2010 CSP Workshop）
- **North Africa（Desertec)**：2.5GW/year
  (100GW by 2050)
- **Ausralia：500MW/year** (by New Energy Finannce)
- **USA：1.7GW/year** (by New Energy Finannce)
- **India：1GW/year** （2GW/year for CSP & PV
  by SA Gov. @Oct.2009 World Bank conference ）

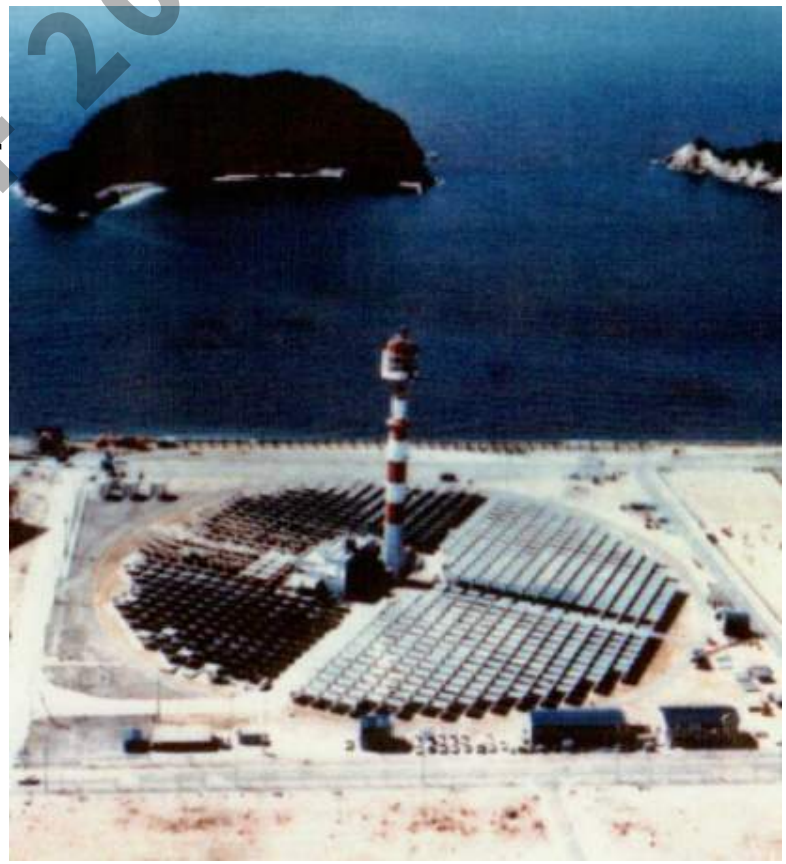
Totally more than 6GW/year, which is lager than the number forecasted by New Energy Finance.

MHI Experience

Project: "Sunshine"
planned by Ministry of Economy, Trade and Industry
conducted by Mitsubishi Heavy Industries
Location: Nio Kagawa, Japan
Duration: 1975 – 1983
(Operation 1981 -1983)
Type: Tower collector, Steam turbine generator
Capacity: 1000kW
Heliostats: 807 units (4m x 4m)
Field: 180m ϕ
Tower: 60m height
Storage: 3Hrs

Heliostat

Receiver



Panoramic view

New Technology to be Developed and Commercialized

☆CSP Gas Turbine cycle

<Advantages ! >

1. High efficiency

CSP **Gas Turbine** cycle: 30% or higher (Target)
CSP Steam Turbine cycle : 16-20%
PV : 8-13%

2. Low Cost of electricity

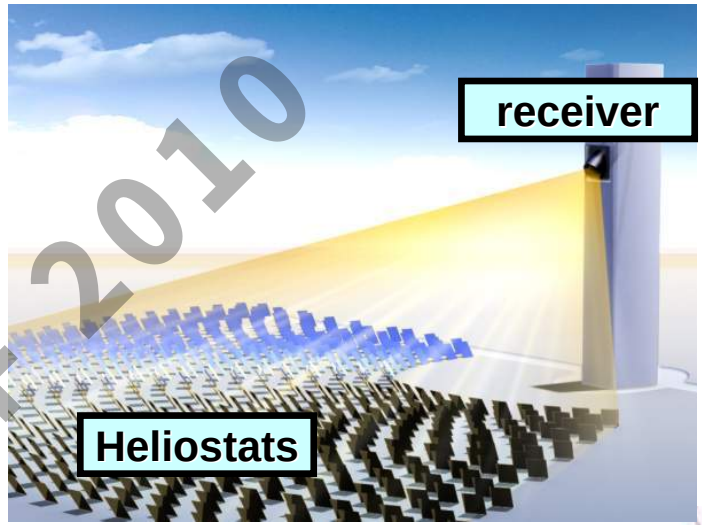
Power generating cost is lower than other systems.

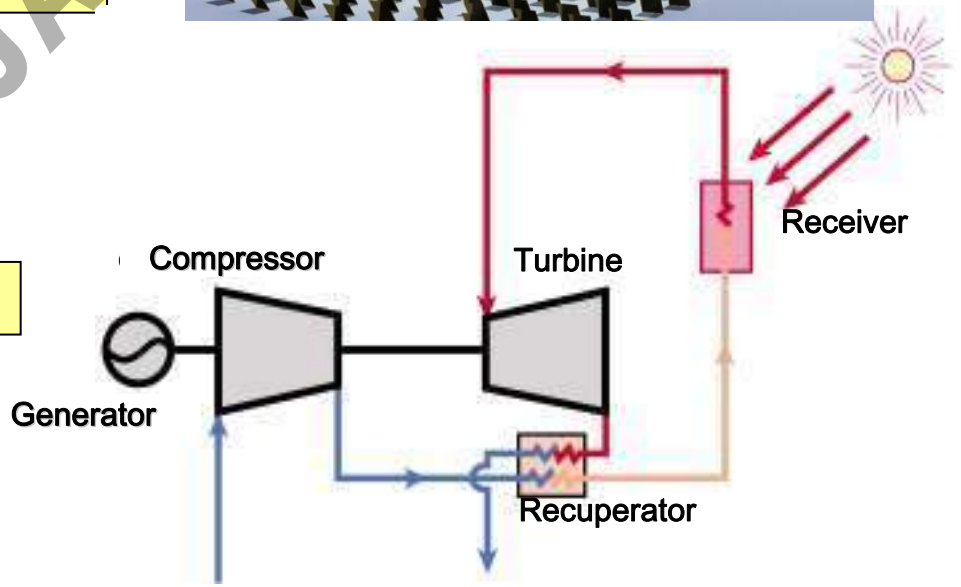
3. Easy Maintenance

Maintenance is much easier than Steam Turbine cycle.

4. No need for water

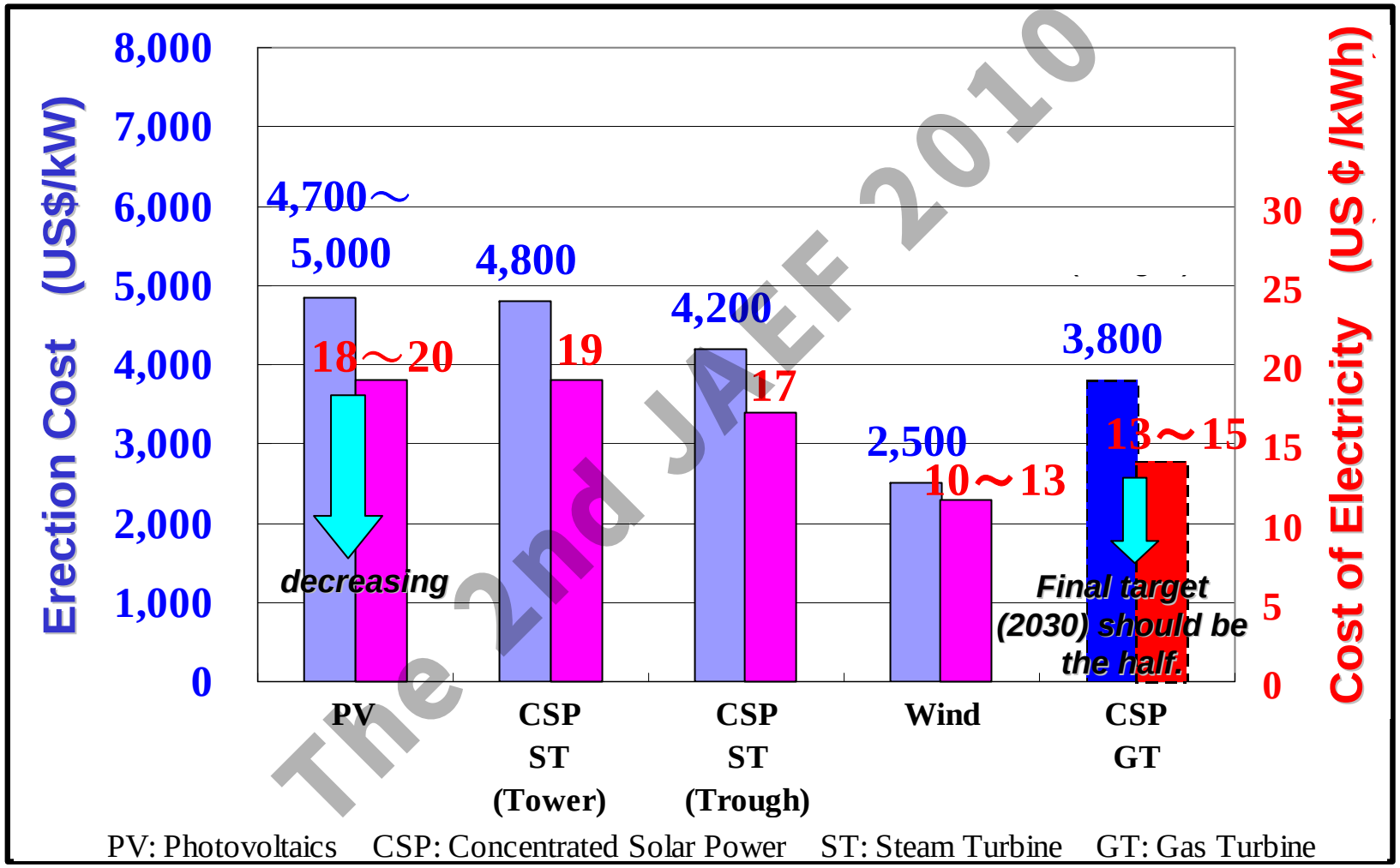
No water is necessary to generate electricity.





CSP Gas Turbine Brayton cycle

Economic Analysis



Importance of Waterless System (1/2)

New York Times **Wednesday, September 30, 2009**

By TODD WOODY

AMARGOSA VALLEY, Nev. —

In a rural corner of Nevada reeling from the recession, a bit of salvation seemed to arrive last year. **A German developer, Solar Millennium**, announced plans to build two large solar farms here that would harness the sun to generate electricity, creating hundreds of jobs.

But then things got messy. **The company revealed that its preferred method of cooling the power plants would consume 1.3 billion gallons of water a year, about 20 percent of this desert valley's available water.**

Now Solar Millennium finds itself in the midst of a new-age version of a Western water war. The public is divided, pitting some people who hope to make money selling water rights to the company against others concerned about the project's impact on the community and the environment.

"I'm worried about my well and the wells of my neighbors," George Tucker, a retired chemical engineer, said on a blazing afternoon.

Here is an inconvenient truth about renewable energy: It can sometimes demand a huge amount of water. Many of the proposed solutions to the nation's energy problems, from certain types of solar farms to biofuel refineries to cleaner coal plants, could consume billions of gallons of water every year.

"When push comes to shove, **water could become the real throttle on renewable energy," said Michael E. Webber, an assistant professor at the University of Texas in Austin who studies the relationship between energy and water.**

While water is particularly scarce in the West, it is becoming a problem all over the country as the population grows. **Daniel M. Kammen, director of the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley,** predicted that as intensive renewable energy development spreads, water issues will follow.

"When we start getting 20 percent, 30 percent or 40 percent of our power from renewables," Mr. Kammen said, "water will be a key issue."

Importance of Waterless System (2/2)

THE ARIZONA REPUBLIC **Jun. 26, 2010**

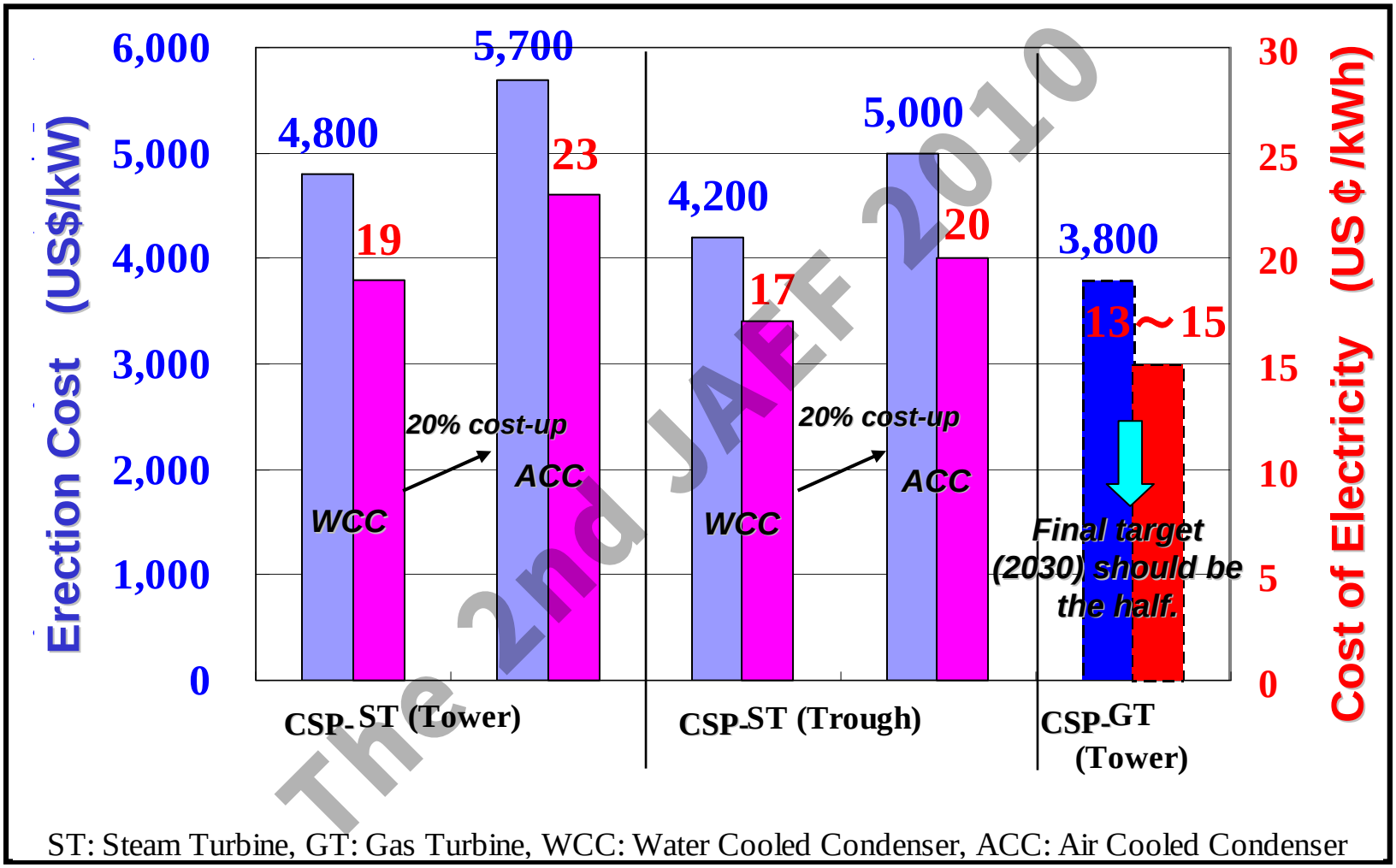
http://www.azcentral.com/arizonarepublic/opinions/articles/2010/06/26/20100626satlets264.html

A US senator from Arizona wrote

- **The EPA shares my concerns regarding wet-cooled CSP, and has submitted public comments on the draft Environmental Impact Statement for one of them, the Sonoran Solar Energy Project (SSEP). It strongly recommended that the SSEP proposal to use wet cooling be rejected and dry cooling be required for the project.**

- **I look forward to working with policymakers in our state to ensure that the right kind of solar technology is deployed in our state, thereby protecting our water supply for generations to come. - Jon Kyle, *Phoenix***

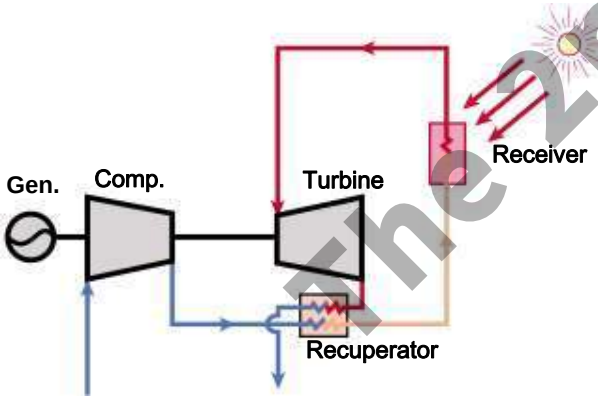
Economic Analysis 2



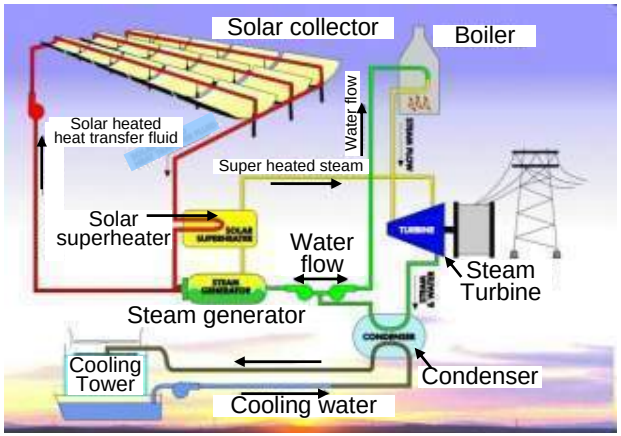
ST: Steam Turbine, GT: Gas Turbine, WCC: Water Cooled Condenser, ACC: Air Cooled Condenser

Maintenance

Type	GT-CSP	ST-CSP
Number of components	Small Refer to the below system diagram.	Large Refer to the below system diagram.
Pipe length	Short	Long
Heat transfer medium	Air only	Oil, Molten salt, Steam
Cooling water	N/A	Necessary
Total Evaluation	★★★ Easy	★ Burdensome



GT schematic diagram (GT Tower)



SEGS schematic diagram (ST Trough)

Test of Receiver in Australia

- **To accelerate commercialization that is scheduled to commence in 2013, MHI has entered into a contract with CSIRO in Australia for the collaborative research on this technology.**

  (CSIRO : Australia's Commonwealth Scientific and Industrial Research Organization)

- **Air heating test of Receiver (600kW$_{th}$) designed by MHI will be conducted at CSIRO in 2010/2011.**
  - **Thermal and Fluid performance will be confirmed.**
  - **Structural integrity, strength and durability will be verified.**

Arrangement of test receiver

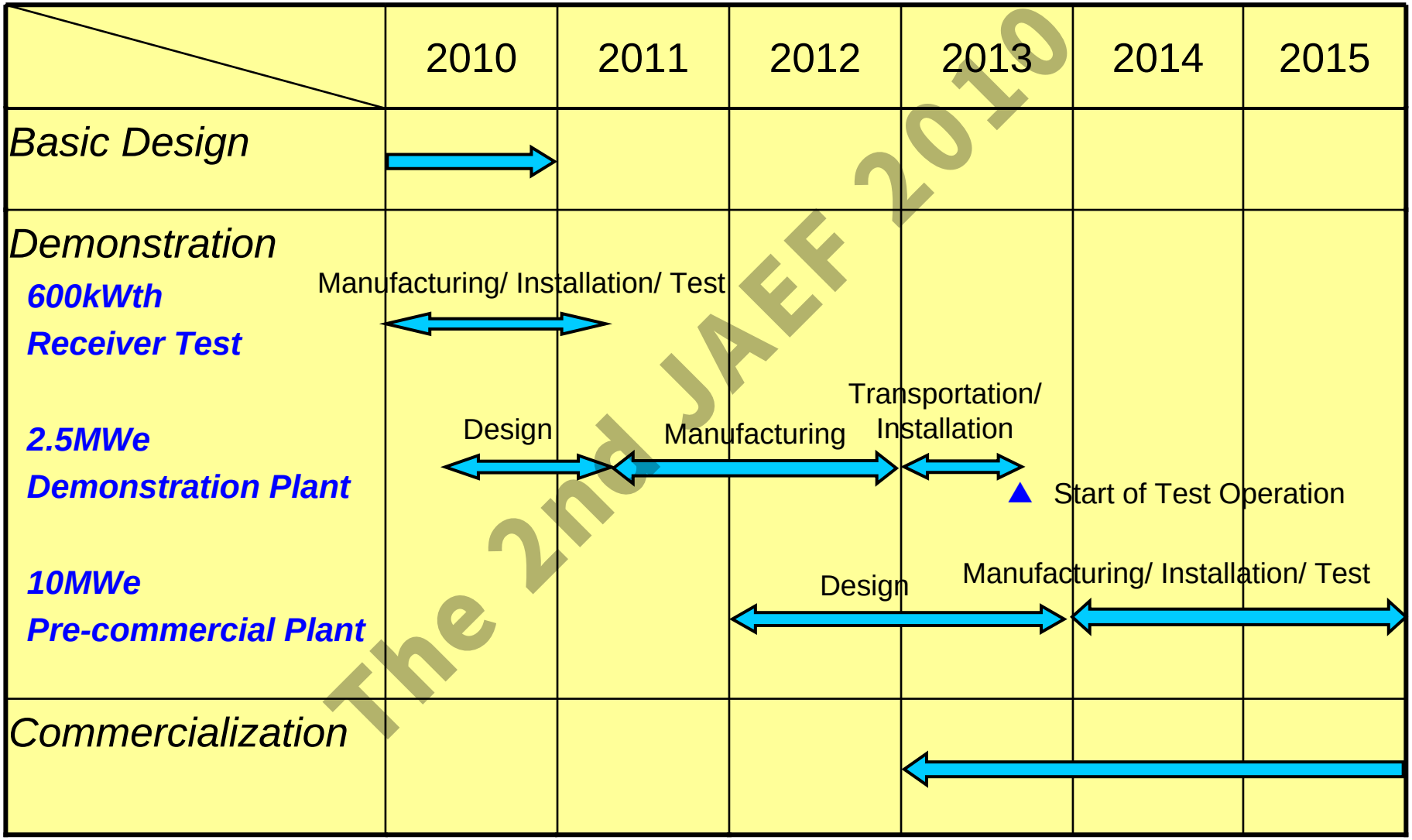
10MW Power Generation System Plan (Example)

Tower height	100m or higher
Heliostat number	About 600
Max. power	10 MW
Annual energy production	17,520 MWh/year
Capacity factor	20%

Location – Some point in 20 degrees latitude area

※ Field size is to be optimized.

Development/Commercialization Schedule



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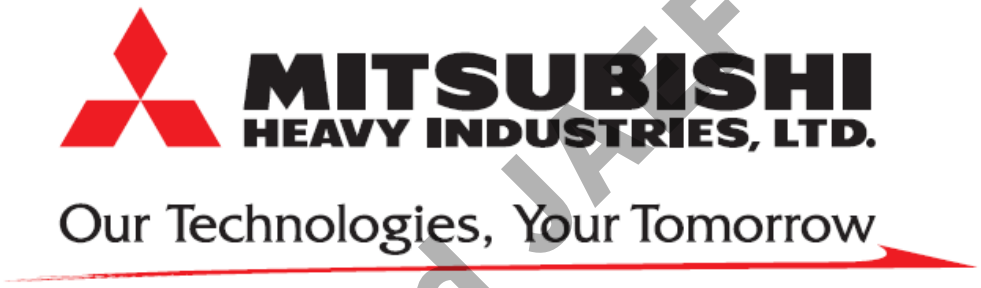

URL: http:www.mhi.co.jp

Contact: Hiromi Nakatani
New Energy Systems Department
Power Systems Headquarters

Email: hiromi_nakatani@mhi.co.jp