Part 3: Task I: Solar Thermal Electric Systems

Operating Agent:
Mark S. Mehos
National Renewable Energy Laboratory

3.1 Nature of Work & Objectives

Task I addresses the design, testing, demonstration, evaluation, and application of concentrating solar power systems, also known as solar thermal electric systems. This includes parabolic troughs, linear Fresnel collectors, power towers and dish/engine systems. Through technology development and market barrier removal, the focus of SolarPACES Task I is enabling the entry of CSP systems into the commercial market place. The component development and research efforts of Task III (see Part 5 of this report) logically feed Task I as new components become parts of new systems. In return, the results of this Task I provide direction to Task III on new component needs.

3.2 Organization and structure

The Task I Operating Agent is responsible for organization and reporting of Task I activities. As described in the 2007 annual report for this task, Task I is currently focused on two subtasks, 1) the development and population of an international project database for commercial CSP systems under operation, construction, or development and 2) the development of acceptance test procedures and standards for CSP systems.

3.3 Status of the Technology

Concentrating solar power offers the lowest cost option for solar energy today, with expected production costs of less than 20¢/kWh for early commercial plants sited in locations with premium solar resources. Lower costs are expected where additional incentives for CSP systems are available (e.g. the existing U.S. Federal 30% Investment Tax Credit). As the cost of electricity from conventional generation technologies continues to rise, off-takers are becoming increasingly interested in CSP as a viable alternative to other renewable technology options. Concerns over global warming and the increasing likelihood of a global carbon constrained energy market, has further increased this interest.

Concentrating solar power today is represented by four technologies: parabolic troughs, linear Fresnel reflectors, power towers and dish/engine systems. Of these technologies, parabolic troughs, and more recently towers, have been deployed in commercial plants. Nine SEGS plants totaling 354 MW, originally built and operated by LUZ in California in the 1980s and 1990s, are continuing to operate today with performance of most of the plants improving over time. In 2006, two commercial CSP plants began full-scale operation. Acciona, formerly SolarGenix, completed construction of a 64-MW parabolic trough plant near Las Vegas, Nevada. The 64-MW plant was the first new commercial large-scale parabolic trough plant to begin operation in more than 15 years. Abengoa inaugurated PS10, an 11-MW saturated steam central receiver plant located near Sevilla, Spain. Numerous additional plants continued or began construction in 2008 (see below for list of plants in operation or under construction). Andasol One began start up operations near the end of 2008. Several additional plants, including Andasol Two, PS20, Ibersol, and several Abengoa Solnova plants are anticipated to begin operating in 2009. Many other projects are under various stages of development, primarily in Spain, northern Africa, and the southwest U.S. (see project database task for more information on CSP projects in operation, under construction, or under development).

Parabolic troughs are today considered to be fully mature technology, ready for deployment. Early costs for solar-only plants are expected to be in the range of 0.17-0.20 $/kWh in sunny locations where no incentives are offered to reduce costs. In recent years, the five plants at the Kramer Junction site (SEGS III to VII) achieved a 30% reduction in operation and maintenance costs, record annual plant efficiency of 14%, and a daily solar-to-electric efficiency near 20%, as well as peak efficiencies up to 21.5%. Annual and design point efficiencies for the current generation of parabolic trough plants under construction in the U.S. and Spain are expected to be even higher based on the current generation of heat collection elements being furnished to the plants by both Solel and Schott.

Hybrid solar/fossil plants have received much greater attention in recent years, and several Integrated Solar Combined Cycle (ISCC) projects are now under construction in the Mediterranean region and the U.S. New Energy Algeria (NEAL) selected Abengoa to build the first such project at Hassi-R’mel. The project will consist of a 150MW ISCCS with 30 MW solar capacity. A similar project is under construction in Morocco where again Abengoa has been selected to build the plant. Achimede is another example of an ISCCS project, however the plant’s 31,000m^2 parabolic trough solar field will be the first to use a molten salt as a heat transfer fluid.

Advanced technologies like Direct Steam Generation (DISS) are under development at the Plataforma Solar de Almeria where researchers continue to compare direct steam, using a combination of sensible heat storage and latent heat storage, with oil based heat transfer fluids. Research on higher temperature heat transfer fluids and lower cost storage systems are also being pursued.

Linear Fresnel systems are conceptually simple, using inexpensive, compact optics, and are being designed to produce saturated or superheated steam. This technology may be suited for integration into combined cycle recovery boilers; i.e., to replace the bled extracted steam in regenerative Rankine power cycles or for saturated steam turbines. Extensive testing experience at a prototype-scale has been underway for several year at the Liddell power station in Australia. Systems are also under development by MAN/SPG (Germany).

Power towers technology, a.k.a. central receiver technology, have completed the proof-of-concept stage of development and, although less mature than parabolic trough technology, are on the verge of commercialization. The most extensive operating experience has been accumulated by several European pilot projects at the Plataforma Solar de Almería in Spain, and the 10-MW Solar One and Solar Two facilities in California.

Construction of PS10, the first commercial power tower, was completed by Solucar at its project site outside of Seville, Spain and has been operating successfully since 2007. The tower system uses a saturated steam receiver to deliver steam to an 11-MW saturated steam turbine. PS20, roughly double the size of PS10, is scheduled to become operational in 2009. Brightsource and ESolar are also developing steam-based receiver designs with the intent of delivering superheated steam at higher temperatures and pressures.

An alternative to steam receiver systems under development by Solucar, Brightsource, and ESolar is the molten salt tower. This approach offers the potential for very low-cost storage that permits dispatch of solar electricity to meet peak demand periods and a high capacity factor (~70%). A molten-salt power tower three times larger than Solar Two is being designed by Sener for southern Spain. This plant, named Germasolar, is a 17-MW molten-salt tower and is projected to start construction in 2010.

Dish/engine systems are modular units typically between 5 and 25 kW in size. Stirling engines have been pursued most frequently, although other power converters like Brayton turbines and concentrated PV arrays have been considered for integration with dish concentrators. The high solar concentration and operating temperatures of dish/Stirling systems has enabled them to achieve world-record solar-to-electric conversion efficiencies of 30%. However, due to the level of development of these technologies, energy costs are about two times higher than those of parabolic troughs. Dish/engine system development is ongoing in Europe and the USA. Reliability improvement is a main thrust of ongoing work, where the deployment and testing of multiple systems enables more rapid progress. Dish/Stirling systems have traditionally targeted high-value remote power markets, but industry is increasingly interested in pursuing the larger, grid-connected markets.

In Europe, Schlaich Bergermann und Partner have extensively tested several 10-kW systems, based on a structural dish and the Solo 161 kinematic Stirling engine at the Plataforma Solar de Almería. Follow-up activities based on the EuroDish design are being pursued by a European Consortium of SBP, Inabensa, CIEMAT, DLR and others. EuroDish prototype demonstration units are currently being operated in Spain, France, Germany, Italy and India.

In the USA, Stirling Energy Systems (SES) is developing a 25-kW dish/Stirling system for utility-scale markets. Six SES dish/Stirling systems are currently being operated as a mini power plant at Sandia National Laboratories' National Solar Thermal Test Facility in Albuquerque, NM, USA. SES has two power purchase agreements to install 800 MW of these 25-kW systems in California, USA.

3.4 Reported Task I activities

The focus of Task I efforts has continued on development of the international project database for CSP systems as well as facilitating discussions related to the development of procedures and test standards for CSP systems. Both efforts are described briefly below.

3.4.1 SolarPACES international Project Database

Description of Project Database Activity

Table 1 provides a listing of operational CSP systems worldwide. Table 2 provides a listing of most of those currently under construction. Data for most of these systems have been provided by the contact points listed and will be made available through a project database located on the SolarPACES website by mid-2009. Examples data provided for some of the systems listed in the table are described in more detail below.

3.4.2 SolarPACES international Standards

Description of Standards Development Activity

A task meeting was held following the 2008 14th Biennial CSP SolarPACES Symposium held in Las Vegas, NV. Those attending the meeting expressed interest in organizing a working group to further define a program for developing procedures and test standards for CSP systems, with an initial emphasis on procedures for acceptance testing of parabolic trough solar fields. It was agreed that a preparatory workshop would be held at NREL in conjunction with Task III. The objective of the preparatory workshop will be to organize and to gather

Table 3.1. CSP Systems in Operation

COMMERCIAL CSP SYSTEMS	CONTACT	Sharing			
		I	M	T	C
Operational Systems					
SEGS I-II	Philip Jones - Cogentrix	x			
SEGS III-IX	Dan Brake – NextEra Energy Resources	x			
Nevada Solar One	Asun Padrós – Acciona Solar Power	x			
Saguaro	Phil Smithers – Arizona Public Service	x			
PS10/PS20	Ana Cabañas – Abengoa Solar	x			
Andasol 1	Manuel Cortés – ACS Cobra	x			
Liddell Power Station	David Mills – Ausra	x			
Kimberlina Power Station	David Mills – Ausra	x			
PE 1	Novatec Biosol				
Jülich Solar Tower					

Table 3.2. CSP Systems Under Construction

COMMERCIAL CSP SYSTEMS	CONTACT	Sharing			
		I	M	T	C
Systems Under Construction					
Manchasol 1	Manuel Cortés – ACS Cobra	x			
La Dehesa	Javier del Pico – Renovables SAMCA	x			
La Florida	Javier del Pico - Renovables SAMCA	x			
Lebrija 1	Carlos Cachadiña – Soleval	x			
Palma Del Rio II	Asun Padrós – Acciona Solar Power	x			
Alvarado 1	Asun Padrós – Acciona Solar Power	x			
Majadas I	Asun Padrós – Acciona Solar Power	x			
Andasol 2	Manuel Cortés – ACS Cobra	x			
Archimede	Massimo Falchetta – NEA	x			
Extresol 1&2	Manuel Cortés – ACS Cobra	x			
Ibersol Cuidad Real		x			
Solnova 1,3&4	Ana Cabañas – Abengoa Solar	x			
Gemasolar Thermosolar Plant		x			

expert opinions on the subject of testing and standards in preparation for a follow on open workshop coincident with the 2009 SolarPACES Symposium scheduled for September in Berlin.

3.5 OPERATIONAL PLANTS

Solar Electric Generating Station VI

The information provided on Solar Electric Generating Station VI, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

SEGS VI is one of the nine Solar Electric Generating Station plants in California's Mojave Desert. The combined electric generating capacity of these plants, which use parabolic trough technology, is more than 350 megawatts. The plants operate as Qualifying Facility Independent Power Producers under the Public Utility Regulatory Policies Act, with a special Standard Offer 2 type of power purchase agreement to Southern California Edison.

Status Date:	April 17, 2009

Background

Solar Resource:	2,725 kWh/m^2/yr
Contact(s):	NextEra
Start Production:	February 1, 1989

Project Overview	
Project Name:	Solar Electric Generating Station VI (SEGS VI)
Country:	United States
Location:	Kramer Junction, California
Owner(s):	NextEra
Technology:	Parabolic trough
Turbine Capacity (Gross):	30 MW
Status:	Operational
Start Year:	1989

Participants

Developer:	Luz
Owner(s) (%):	NextEra (41%)
Operator(s):	NextEra
Generation Offtaker(s):	Southern California Edison

Plant Configuration

Solar Field

Solar-Field Aperture Area:	188,000 m^2
SCA Manufacturer (Model):	Luz (LS-2)
HCE Manufacturer:	Solel Solar Systems (Solel UVAC)
HCE Type (Length):	Evacuated tube (4 meters)
Heat-Transfer Fluid Type:	Therminol
Solar-Field Outlet Temp.:	390°C

Power Block

Turbine Capacity (Gross):	30 MW
Power Cycle:	MHI regenerative steam turbine, solar preheat and steam generation, natural-gas-fired superheater
Power-Cycle Pressure:	100 bars
Engine/Turbine Efficiency:	37.5% @ full load
Fossil Backup Type:	Natural gas

Thermal Storage

Storage Capacity:	0 hours

Solar Electric Generating Station IX

The information provided on Solar Electric Generating Station IX, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

SEGS IX is one of the nine Solar Electric Generating Station plants in California's Mojave Desert. The combined electric generating capacity of these plants, which use parabolic trough technology, is more than 350 megawatts. The plants operate as Qualifying Facility Independent Power Producers under the Public Utility Regulatory Policies Act, with a special Standard Offer 2 type of power purchase agreement to Southern California Edison.

Project Overview	
Project Name:	Solar Electric Generating Station IX (SEGS IX)
Country:	United States
Location:	Harper Dry Lake, California
Owner(s):	NextEra
Technology:	Parabolic trough
Turbine Capacity (Gross):	89 MW
Status:	Operational
Start Year:	1990

Status Date: April 17, 2009

Background

Solar Resource:	2,725 kWh/m²/yr
Contact(s):	NextEra
Start Production:	October 1, 1990

Participants

Developer:	Luz
Owner(s) (%):	NextEra (50%)
Operator(s):	NextEra
Generation Offtaker(s):	Southern California Edison

Plant Configuration

Solar Field

Solar-Field Aperture Area:	483,960 m²
SCA Manufacturer (Model):	Luz (LS-3)
HCE Manufacturer:	Solel Solar Systems (Solel UVAC)
HCE Type (Length):	Evacuated tube (4 meters)
Heat-Transfer Fluid Type:	Therminol
Solar-Field Outlet Temp.:	390°C

Power Block

Turbine Capacity (Gross):	89 MW
Power Cycle:	MHI regenerative steam turbine, solar preheat and steam generation, natural-gas-fired superheater
Power-Cycle Pressure:	100 bars
Engine/Turbine Efficiency:	37.6% @ full load
Fossil Backup Type:	Natural gas

Thermal Storage

Storage Capacity:	0 hours

Nevada Solar One

The information provided on Nevada Solar One, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Acciona Energy's Nevada Solar One is the third largest CSP plant in the world and the first plant built in the United States since 1999. Located in Boulder City, Nevada, about 40 miles southeast of Las Vegas, this parabolic trough system has been operating since June 2007. The US$260 million plant has a nominal production capacity of 64 megawatts with a maximum capacity of 70 megawatts. All of the plant's electricity, which can power more than 14,000 households annually, is being sold to Nevada Energy under a long-term power purchase agreement.

Status Date: April 30, 2009

Background

Lat/Long Location:	35°56'0"N, 114°53'0"W
Land Area:	400 acres
Solar Resource:	2,700 kWh/m²/yr
Electricity Generation:	134,000 MWh/yr
Contact(s):	Asun Padrós , Acciona Energía
Break Ground:	February 11, 2006
Start Production:	June, 2007
Cost:	266,000,000 USD
Annual Net Solar Electric Generation:	2,000 MWh AC (projected)
Construction Job-Years:	350
Annual O&M Jobs:	30

Project Overview	
Project Name:	Nevada Solar One (NSO)
Country:	United States
Location:	Boulder City, Nevada
Owner(s):	Acciona Energy, Solargenix Energy Inc.
Technology:	Parabolic trough
Turbine Capacity (Net):	64 MW
Status:	Operational
Start Year:	2007

Participants

Developer:	Acciona Solar Power
Owner(s) (%):	Acciona Energia (100%)
EPC Contractor(s):	Lauren Engineering
Operator(s):	Acciona Solar Power
Generation Offtaker(s):	Nevada Energy

Plant Configuration

Solar Field

Solar-Field Aperture Area:	357,200 m²
# of SCAs:	760
SCA Manufacturer (Model):	Acciona Solar Power (SGX-2)
SCA Drive Manufacturer(s):	Parker Hannifin, Ansco Machine Company
Mirror Manufacturer (Model):	Flabeg (LS2)
# of Heat Collector Elements (HCEs):	11,136 / 7,104
HCE Manufacturer (Model):	Schott Glass (Schott PTR70) / Solel Solar Systems (Solel UVAC)
HCE Type (Length):	Evacuated tube (4 meters)
Heat-Transfer Fluid Type:	Biphenyl/Diphenyl oxide
Solar-Field Inlet Temp.:	318°C
Solar-Filed Outlet Temp.:	393°C

Power Block

Turbine Capacity (Gross):	70 MW
Turbine Capacity (Net):	64 MW
Turbine Manufacturer:	Siemens (Sweden)
Power Cycle:	Reheat steam Rankine cycle
Power-Cycle Pressure:	100 bars

Cooling Method: Wet cooling
Engine/Turbine Efficiency: 37.6% @ full load
Fossil Backup Type (%): Natural gas (2%)

Thermal Storage
Description: Oversized field piping provides 0.5 hour of storage at full load

Andasol-1

The information provided on Andasol-1, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Andasol-1 is the first parabolic trough power plant in Europe. Located in southern Spain, this 300 million Euro power plant has been under construction since June 2006 and began operating in 2008. The nominal production capacity of 50 megawatts is enough electricity for up to 200,000 people. A two-tank indirect thermal storage system holds 28,500 tons of molten salt, and this reservoir can run the turbine for up to 7.5 hours at full load. Andasol-1 and two upcoming companion plants will help the Spanish power grid meet peak summer demand primarily caused by the high energy consumption of air conditioning units.

Status Date: April 27, 2009

Project Overview	
Project Name:	Andasol-1 (AS-1)
Country:	Spain
Location:	Aldiere, Granada
Owner(s):	ACS/Cobra Group, Solar Millennium Group
Technology:	Parabolic trough
Turbine Capacity (Net):	49.9 MW
Status:	Operational
Start Year:	2008

Background

Lat/Long Location: 37°13'50.83"N, 3°4'14.08"W
Land Area: 200 hectares
Solar Resource: 2,136 kWh/m²/yr
Electricity Generation: 158,000 MWh/yr (expected)
Contact(s): Manuel Cortés, Maria Sanchez, ACS/Cobra Group
Company Web: www.grupocobra.com, www.grupoacs.com
Break Ground: July 3, 2006
Production Date: November 26, 2008
Construction Job-Years: 600
Annual O&M Jobs: 40
PPA/Tariff Date: September 15, 2008
Tariff Rate: 27 euro cents per kWh
Tariff Period: 25 years
Tariff Information: Real Decreto 661/2007

Participants

Developer: ACS/Cobra Group
Owner(s) (%): ACS/Cobra Group (75%), Solar Millennium Group (25%)
EPC Contractor(s): UTE CT Andasol-1: Cobra (80%) and Sener (20%)
Operator(s): Cobra O&M
Generation Offtaker(s): Endesa

Plant Configuration

Solar Field

Solar-Field Aperture Area: 510,120 m²
# of SCAs: 624
# of Loops: 156
SCAs per Loop: 4
SCA Length: 144 m
Modules per SCA: 12
SCA Manufacturer (Model): UTE CT Andasol-1 (SKAL-ET)
Mirror Manufacturer (Model): Flabeg (RP3)

# of Heat Collector Elements (HCEs):	11,232 / 11,232
HCE Manufacturer:	Schott / Solel
HCE Length:	4 m / 4 m
Heat-Transfer Fluid Type:	Diphenyl/Biphenyl oxide
Solar-Field Inlet Temp.:	293°C
Solar-Field Outlet Temp.:	393°C

Power Block

Turbine Capacity (Net):	49.9 MW
Turbine Manufacturer:	Siemens (Germany)
Power Cycle:	Rankine cycle
Power-Cycle Pressure:	100 bars
Cooling Method:	Wet cooling
Cooling Method Description:	Cooling towers
Engine/Turbine Efficiency:	38.1% @ full load
Annual Solar-to-Electric Efficiency:	16%
Fossil Backup Type (%):	HTF heater (12%)

Thermal Storage

Storage Type:	2-tank indirect
Storage Capacity:	7.5 hours
Thermal Storage Description:	28,500 tons of molten salt, 60% sodium nitrate, 40% potassium nitrate. 1010 MWh. Tanks are 14 m high and 36 m in diameter

Planta Solar 10

The information provided on Planta Solar 10, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Solúcar Energía's Planta Solar 10 is the first solar central-receiver system producing grid-connected electricity under a purely commercial approach. PS10's technologies—including glass-metal heliostats, pressurized-water thermal storage system, and saturated-steam receiver and turbine—were previously tested and qualified at the Plataforma Solar de Almería facility. This testing helped to avoid technological uncertainties and allowed the project to focus on scaling up, integrating subsystems, demonstrating dispatchability, and reducing O&M costs. The plant's thermal storage system has a 50-minute capacity at 50% load to handle cloud transients. The tower was designed to reduce visual impact—its relatively narrow body includes a large open space to give a lightweight sense.

Status Date: April 21, 2009

Background

Lat/Long Location:	37°26'30.97"N, 6°14'59.98"W
Land Area:	55 hectares
Solar Resource:	2,012 kWh/m²/yr
Electricity Generation:	23,400 MWh/yr (expected)
Contact(s):	Ana Cabañas, Abengoa Solar
Company Web:	www.abengoasolar.com
Break Ground:	2005
Production Date:	June 25, 2007
PPA/Tariff Date:	January 17, 2005
Tariff Rate:	27.1188 euro cents per kWh
Tariff Period:	25 years
Tariff Information:	Royal Decree 661/2007; Total Price = Pool + Tariff Rate
Project Type:	Commercial plant

Incentive 1:	5.0 million euros from European Commission under FP5
Incentive 2:	1.2 million euros from Andalusian Regional Government

Participants

Developer:	Abengoa Solar
Owner(s) (%):	Abengoa Solar
EPC Contractor(s):	Abener Energía
Operator(s):	Abengoa Solar
Generation Offtaker(s):	Endesa Distribución (FIT);
Electric market (pool)	

Project Overview	
Project Name:	Planta Solar 10 (PS10)
Country:	Spain
Location:	Sevilla, Sanlucar la Mayor
Owner(s):	Solucar Energia, S.A.; Ibabensa, CIEMAT, DLR, Fichtner
Technology:	Power tower
Turbine Capacity (Net):	11 MW
Status:	Operational
Start Year:	2007

Plant Configuration

Solar Field

Heliostat Solar-Field Aperture Area:	75,000 m^2
# of Heliostats:	624
Heliostat Aperture Area:	120 m^2
Heliostat Manufacturer (Model):	Abengoa (Solucar 120)
Heliostat Description:	Glass-metal
Tower Height:	115 m
Tower Configuration:	North-facing receiver
Receiver Manufacturer:	Technical-Tecnicas Reunidas
Receiver Type:	Cavity
Heat-Transfer Fluid Type:	Water
Receiver Outlet Temp.:	250°-300°C

Power Block

Turbine Capacity (Gross):	11.02 MW
Turbine Capacity (Net):	50 MW
Power Cycle:	Rankine cycle
Power-Cycle Pressure:	45 bars
Cooling Method:	Wet cooling
Cooling Method Description:	Refrigeration towers
Fossil Backup Type (%):	Natural gas (15%)

Thermal Storage

Storage Type:	Other
Storage Capacity:	1 hour

Kimberlina Solar Thermal Power Plant

The information provided on Kimberlina, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Kimberlina is the first Compact Linear Fresnel Reflector (CLFR) project in North America and is the first major solar thermal power plant to be built in California in nearly two decades. Located in Bakersfield, CA, Ausra began construction of the power plant in March 2008, with the plant entering operation in October 2008. Kimberlina will generate up to 5 megawatts of electricity at full output to help meet California's peak summer demand. Kimberlina's direct steam generation eliminates the need for heat-transfer fluids, such as synthetic oils, and uses common materials, including carbon steel and standard flat glass to allow for rapid scale-up.

Status Date: May 11, 2009

Background

Lat/Long Location: 35°34'0"N, 119°11'39.1"W
Land Area: 12 acres
Contact(s): Bill Conton, Katherine Potter; Ausra
Key References: New Release, Overview
Break Ground: March, 2008
Start Production: October, 2008
Project Type: Demonstration
Incentives: Federal investment tax credit, anticipated
Annual O&M Jobs: 7

Project Overview	
Project Name:	Kimberlina Solar Thermal Power Plant (Kimberlina)
Country:	United States
Location:	Bakersfield, California
Owner(s):	Ausra
Technology:	Linear Fresnel ref-flector
Turbine Capacity (Net):	5 MW
Status:	Operational
Start Year:	2008

Participants

Developer: Ausra
Owner(s) (%): Ausra (100%)
Operator(s): Ausra
Generation Offtaker(s): CA ISO

Plant Configuration

Solar Field

Solar-Field Aperture Area: 26,000 m^2
# of Lines: 3
Line Length: 385 m
Mirror Width in Line: 2 m
# of Mirrors across Line: 10
Collector Manufacturer (Model): Ausra
Collector Description: Compact Linear Fresnel
Mirror Manufacturer (Model): Ausra
Drive Manufacturer(s): Ausra
Receiver Manufacturer (Model): Ausra
Receiver Type: Non-evacuated
Receiver Length: 385 m
Heat-Transfer Fluid Type: Water

Power Block

Turbine Capacity (Net): 5 MW
Power-Cycle Pressure: 40 bars

Thermal Storage

3.6 PLANTS UNDER CONSTRUCTION

Archimede

The information provided on Archimede, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Archimede is a parabolic trough plant being constructed in Sicily, Italy. The plant will produce steam (4.72-MW equivalent) to be sent to a combined-cycle steam turbine rated at 130 MW. A 2-tank direct system will provide 8 hours of thermal storage.

Status Date: April 10, 2009

Background

Lat/Long Location:	37°8'3.12"N, 15°13'0.15"E
Land Area:	8 hectares
Solar Resource (Source):	1,936 kWh/m²/yr (ENEA/ENEL)
Contact(s):	Massimo Falchetta, ENEA
Break Ground:	July 21, 2008
Start Production:	May 30, 2010 (expected)
Annual Net Solar Electric Generation:	9,200 MWh/yr (expected/planned)

Participants

Developer:	ENEL
Owner(s) (%):	ENEL (100%)
Operator(s):	ENEL

Project Overview	
Project Name:	Archimede
Country:	Italy
Location:	Priolo Gargallo, Sicily
Owner(s):	ENEL
Technology:	Parabolic trough
Turbine Capacity (Gross):	4.72 MW
Status:	Under construction
Start Year:	2010

Plant Configuration

Solar Field

Solar-Field Aperture Area:	31,860 m²
# of SCAs:	54
# of Loops:	9
# SCAs per Loop:	6
SCA Aperture Area:	590 m²
SCA Length:	100 m
# of Modules per SCA:	8
SCA Manufacturer (Model):	COMES (ENEA)
Mirror Manufacturer:	Ronda Reflex
# of HCEs:	1,296
HCE Manufacturer:	Archimede Solar Energy
Heat-Transfer Fluid Type:	Molten salt (60% $NaNO_3$ + 40% KNO_3)
Solar-Field Inlet Temp.:	290°C
Solar-Field Outlet Temp.:	550°C
Temp. Difference:	260°C

Power Block

Turbine Capacity (Net):	4.72 MW equivalent
Turbine Manufacturer:	Tosi
Turbine Description:	The plant produces steam that is sent to the CC steam turbine, rated at 130 MW; the 4.72 MW datum is the calculated capacity added by the solar steam.
Power Cycle:	Rankine cycle
Power-Cycle Pressure:	93.83 bars
Cooling Type:	Wet cooling
Engine/Turbine Efficiency:	39.30% @ full load
Fossil Backup Type:	Natural gas
Annual Solar-to-Electric Efficiency:	15.60%

Thermal Storage

Thermal Storage Type:	2-tank direct
Storage Capacity:	8 hours
Thermal Storage Description:	Total of 1,580 tons of molten salt, 60% sodium nitrate, 40% potassium nitrate. Capacity 100 MWh (thermal). Tanks are 6.5 m high and 13.5 m in diameter

Ibersol Ciudad Real (Puertollano)

The information provided on Ibersol Cuidad Real (Puertollano), a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Status Date:	April 16, 2009

Background

Lat/Long Location:	38°38'36.19"N, 3°58'29.6"W
Land Area:	150 hectares
Solar Resource:	2,061 kWh/m²/yr
Electricity Generation:	103,000 MWh/yr (expected)
Break Ground:	March, 2007
Production Date:	May, 2009 (estimated)
Cost:	200,000,000 euros
Construction Job-Years:	200 average; 650 peak
Annual O&M Jobs:	60
Tariff Period:	25 years
Tariff Information:	Market price with premium system

Participants

Developer:	IBERCAM (Iberdrola Renovables Castilla-La Mancha)
Owner(s) (%):	IBERCAM (90%), IDAE (10%)
Operator(s):	Iberdrola Renovables
Generation Offtaker(s):	Market

Project Overview	
Project Name:	Ibersol Ciudad Real (Puertollano)
Country:	Spain
Location:	Puertollano, Castilla-La Mancha
Owner(s):	IBERCAM, IDAE
Technology:	Parabolic trough
Turbine Capacity (Net):	50 MW
Status:	Under commissioning
Start Year:	2009

Plant Configuration

Solar Field

Solar-Field Aperture Area:	287,760 m²
# of SCAs:	352
# of Loops:	88
# SCAs per Loop:	4
# Modules per SCA:	12
SCA Manufacturer (Model):	Iderdrola Collector
Mirror Manufacturer (Model):	Flabeg, Rioglass
# of Heat Collector Elements (HCEs):	6,336 / 6,336
HCE Manufacturer:	Schott / Solel
HCE Length:	4 m / 4 m
Heat-Transfer Fluid Type:	Diphenyl/Diphenyl oxide
HTF Company:	Dow Chemical
Solar-Field Inlet Temp.:	304°C
Solar-Field Outlet Temp.:	391°C

Power Block

Turbine Capacity (Net):	50 MW
Turbine Manufacturer:	Siemens
Power Cycle:	Rankine cycle
Power-Cycle Pressure:	100 bars
Cooling Method:	Wet cooling
Engine/Turbine Efficiency:	38.9% @ full load
Fossil Backup Type:	HTF heater (gas-fired)

Thermal Storage

Gemasolar Thermosolar Plant

The information provided on Gemasolar Thermosolar Plant, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Status Date:	April 17, 2009

Background

Lat/Long Location:	37°33'40.95"N, 5°19'49.39"W
Land Area:	190 hectares
Solar Resource:	2,062 $kWh/m^2/yr$
Electricity Generation:	100,000 MWh/yr (expected)
Contact(s):	Juan Ignacio Burgaleta, Sener
Break Ground:	February, 2009
Start Production:	December, 2010
Cost:	230,000,000 euros
Construction Job-Years:	800
Annual O&M Jobs:	45

Participants

Developer:	Torresol Energy
Owner(s) (%):	Sener (60%), Masdar (40%)
EPC Contractor(s):	UTE C.T. Solar Tres
Operator(s):	Gemasolar 2006, S.A.

Project Overview	
Project Name:	Gemasolar Thermo-solar Plant (Gemasolar)
Country:	Spain
Location:	Fuentes de Andalucia, Sevilla
Owner(s):	Sener, Masdar
Technology:	Central tower and molten-salt receiver
Turbine Capacity (Gross):	17 MW
Status:	Under construction
Start Year:	2010

Plant Configuration

Solar Field

Heliostat Solar-Field Aperture Area:	318,000 m^2
# of Heliostats:	2650
Heliostat Aperture Area:	120 m^2
Heliostat Manufacturer:	Sener
Heliostat Description:	Sheet-metal stamped facet
Heliostat Drive Manufacturer:	Sener
Tower Height:	150 m
Tower Manufacturer:	Sener
Heat-Transfer Fluid Type:	Molten salts (sodium and potassium nitrates)
Receiver Inlet Temp.:	290°C
Receiver Outlet Temp.:	565°C

Power Block

Turbine Capacity (Gross):	17 MW
Power Cycle:	Rankine cycle
Cooling Method:	Wet cooling
Fossil Backup Type:	Natural gas

Thermal Storage

Storage Type:	2-tank direct
Storage Capacity:	15 hours
Thermal Storage Description:	One cold-salt tank (290°C) from where salts are pumped to the tower receiver and heated up to 565°C, to be stored in one hot-salt tank (565°C)

3.7 PLANTS UNDER CONTRACT

Arcosol 50

The information provided on Arcosol 50, a concentrating solar power (CSP) project, is organized by background, participants, and power plant configuration.

Project Overview	
Project Name:	Arcosol 50 (Valle 1)
Country:	Spain
Location:	San José del Valle, Cádiz
Owner(s):	Torresol
Technology:	Parabolic trough
Turbine Capacity (Net):	49.9 MW
Status:	Under contract
Start Year:	

Status Date: April 20, 2009

Background

Lat/Long Location:	36°39’40”N, 5°50’0”W
Land Area:	230 hectares
Solar Resource:	2,097 kWh/m²/yr
Electricity Generation:	175,000 MWh/yr (expected)
Contact(s):	Juan Ignacio Burgaleta, Torresol
Break Ground:	May, 2009
Cost:	320,000,000 Euros
Construction Job-Years:	900
Annual O&M Jobs:	45

Participants

Developer:	Torresol
Owner(s) (%):	Torresol (100%)
EPC Contractor(s):	UTE Valle 1
Operator(s):	Torresol

Plant Configuration

Solar Field

Solar-Field Aperture Area:	510,120 m²
# of SCAs:	624
Heat-Transfer Fluid Type:	Diphenyl/Diphenyl oxide
Solar-Field Inlet Temp.:	293°C
Solar-Field Outlet Temp.:	393°C

Power Block

Turbine Capacity (Net):	49.9 MW
Power Cycle:	Rankine cycle
Power-Cycle Pressure:	100 bars
Cooling Method:	Wet cooling
Engine/Turbine Efficiency:	38.1% @ full load
Fossil Backup Type:	Natural gas

Thermal Storage

Storage Type:	2-tank indirect
Storage Capacity:	7.5 hours
Thermal Storage Description:	28,500 tons of molten salt, 60% sodium nitrate, 40% potassium nitrate