ABENGOA

NREL CSP Technology Workshop

Panel 1 – Central Receivers

PS 10 and PS 20

Power Towers in Seville, Spain

Rafael Osuna Gonzalez-Aguilar
Solucar R&D, General Director

7 March 2007

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Your Partner in Resources and Technical Solutions

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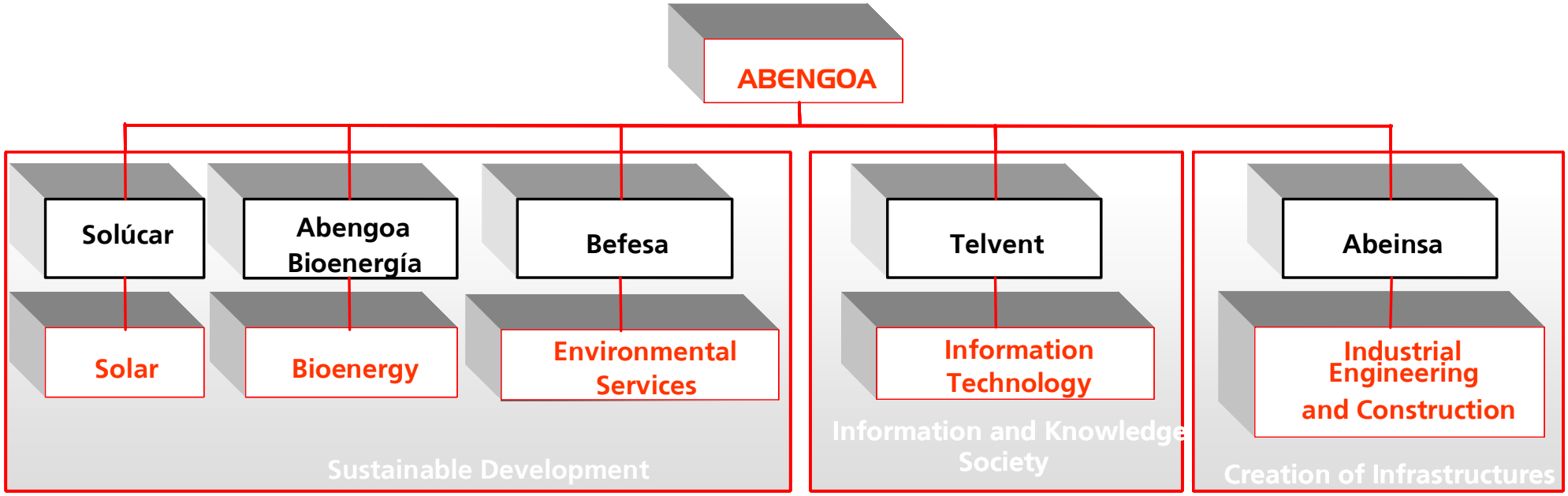

Abengoa is a technology company applying innovative solutions for sustainable development in the infrastructures, environment and energy sectors.

Sales evolution, EBITDA by Bussines Group

Sales

	2005	2004	1995
Solar	-	-	-
Bioenergy	19%	19%	-
Environmental Services	20%	20%	6%
Information Technology	18%	16%	23%
Engineering and Industrial Construction	43%	45%	71%
	100%	100%	100%

EBITDA

	2005	2004	1995
Solar	-	-	-
Bioenergy	20%	22%	-
Environmental Services	19%	20%	1%
Information Technology	15%	15%	31%
Engineering and Industrial Construction	46%	43%	68%
	100%	100%	100%

… in highly innovative fields…

One of worldwide pioneers in Solar energy

Only international Bioenergy company (#1 in Europe, #5 in USA)

Among top five Desalination companies worldwide

ABENGOA

… and a highly skilled Workforce

Average Staff	2005		2004	
Senior Manag.	388	3,5%	346	3,7%
Middle Mnag.	1.117	10,1%	939	10,1%
Engineers and Uni. Graduates	1.613	14,5%	1.217	13,0%
Skilled technicians	1.416	12,8%	1.289	13,9%
Technicians	6.548	59,1%	5.527	59,3%
	11.082	100,0%	9.318	100,0%
Outside Spain	5.082	46,0%	3.984	42,8%
Spain	6.000	54,0%	5.334	57,2%

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Origin of the Activity

Abengoa started the developments in this field during **1984** taking part in the construction of **Plataforma Solar de Almería**. For that Abengoa built various compounds, like **heliostats and facets,** and assembled several equipments in the Cesa tower.

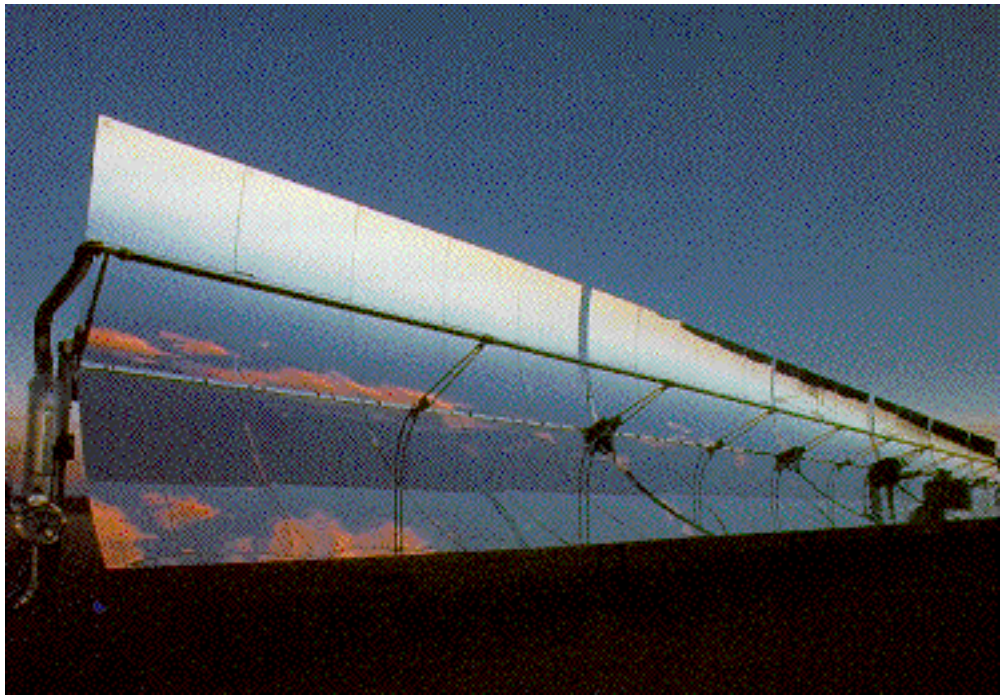
Afterwards in **1987 facets** were also supplied for the heliostats field of **Weizmann Institute** in Israel.

R&D Historic Evolution

During **1990** several R&D activities were started in collaboration with CIEMAT, specifically in the proyect **ACE-20**. This project consisted in the design, manufacture and assembly of a parabolic-trough collector applied to a desalination plant.

Collector ACE20, CIEMAT Parabolic-Trough System

- Length: 53 m
- Weight: 4 Tm
- Aperture: 132.5 m^2
- Reflective area : 147.3 m^2
- Orientation : Norte - Sur
- Movement velocity: 9 º/min y 18 º/min
- Work fluid: Aceite
- Work temperature: 120 ºC - 290 ºC
- Pressure drop: 0.5 bar
- Volume: 4 m^3/h
- Tracking system : in one axis
- Absorber: internal steel pipe treated with black chromium
  external crystal pipe

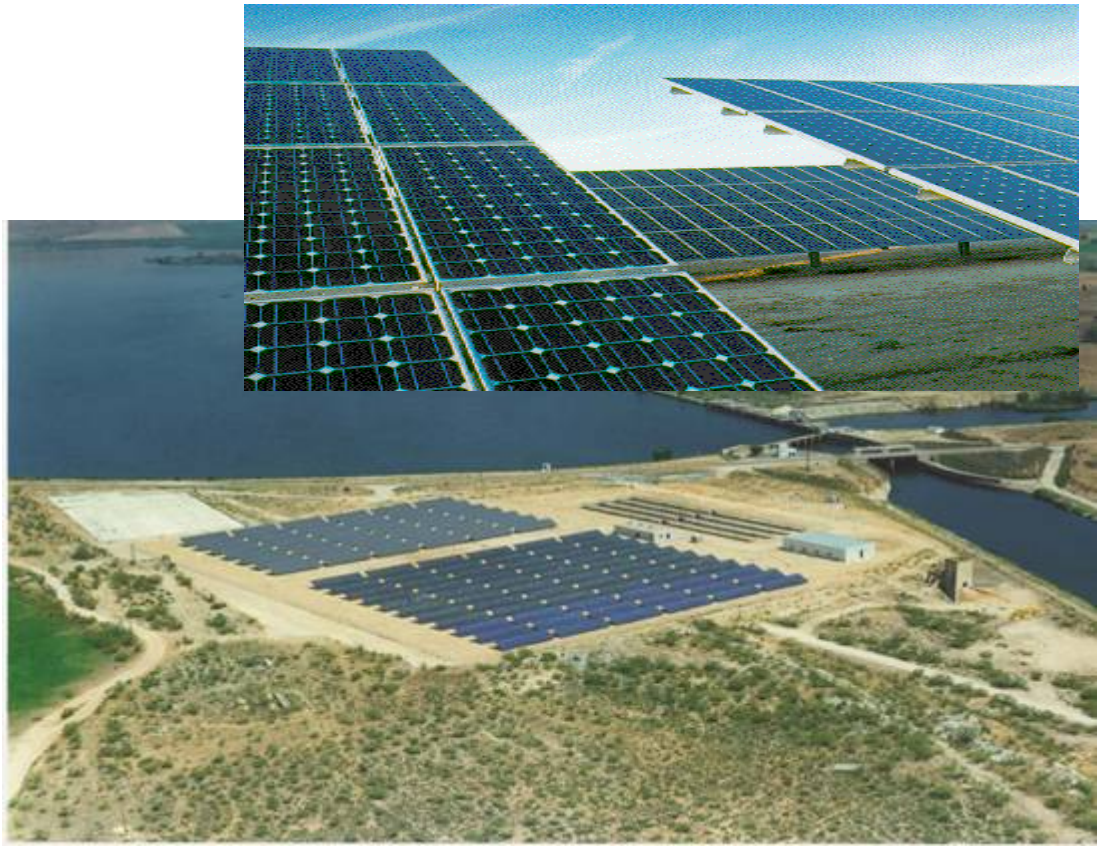


In **1993** the EPC project of **Toledo 1MWp PV Plant** was supplied. This project was leaded by Unión Fenosa, Endesa and Rwe and it was funded by EC. It is located in the Embalse de Castrejón (La Puebla de Montalbán, Toledo).

Toledo 1MW PV Plant
Photovoltaic Plant for Power Generation

	Field 1	Field 2	Field 3
• Max. Power:	456 kWp	423 kWp	101 kWp
• Efficiency:	10 %	14.3 %	14.3 %
• Manufacturer:	NUKEN	BP	BP
• Nº of modules:	2112	4704	1120
• Surface m2:	4309	2940	703

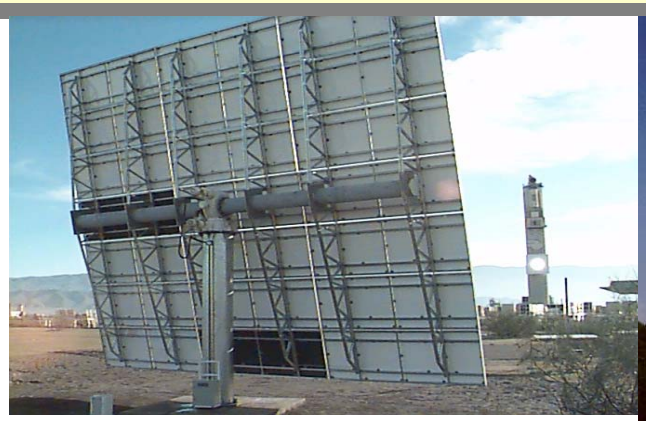
- Shareholders: Unión Fenosa, Endesa, Rwe,
- Constructor: Abengoa
- Participants: Ciemat, Pacsa, Elecnor, Enertron
- Financing U.E.



R&D Historic Evolution

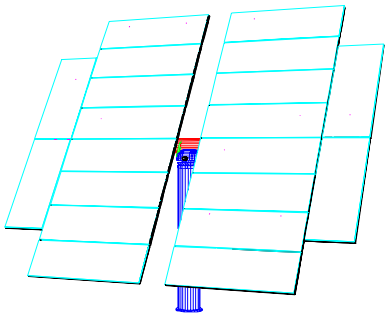
Since **1994** several R&D projects were carried out for the development of differents **heliostat prototypes**. The Framework Programs of UE (IV and V) funded part of them. Projects: **Solgas, Colón Solar**, etc.

An heliostat of 120 m^2 was also built for the **Paul Scherrer Institut**, Switzerland.



Solgas Project : Tower and Heliostats Plant for the Production of Industrial Steam

- Location: Ertisa - Huelva
- Technology: Heliostats field (30 000 m^2) and central tower
- Power in the receiver: 20MW_t
- Integrated solar combinated cycle (I.S.C.C.)
- Heliostats: 450 units, 66 m^2/unit
- Operation: Solar,natural gas
- Share: Sodean, Sevillana, EDP, Abengoa, Ciemat, DLR
- E.C. Funding: APAS Program



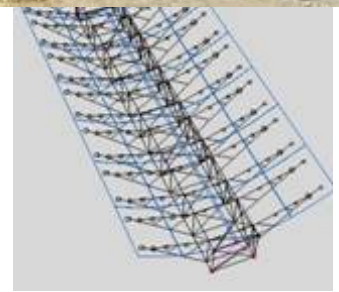
Colón-Solar Project: Tower and Heliostats Plant for Electric Generation:

- Location: Thermal plant Cristóbal Colón, Huelva
- Technology: Heliostats field (35 000 m^2) and tower
- Power in the receptor: 21MW_t
- Power plant: 68.4 MW_e
- Heliostats: 500 uds, 70 m^2/ud
- Operation: Solar,Natural Gas, Fuel
- Share: Sevillana, Endesa, EDP, ABB, B&W, Inabensa, Ciemat, DLR
- E.C. Funding: Thermie Program

R&D Historic Evolution

From **1995 to 2000** several R&D projects with **Parabolic-Through collector** technology (IV y V Framework Program of EC) were developed. The most important projects were:

- **Theseus:** Feasibility study of a plant of 52 MWe in Creta (Grecia).
- **Eurotrough:** Design of a new concept collector lighter and cheaper.
- **DISS:** Direct steam generation with these collectors.



During **1997-1999 Parabolics Dishes** projects were also developed (IV y V Framework Program) :

EuroDish and EnviroDish : Design of new concepts for Dish Systems.

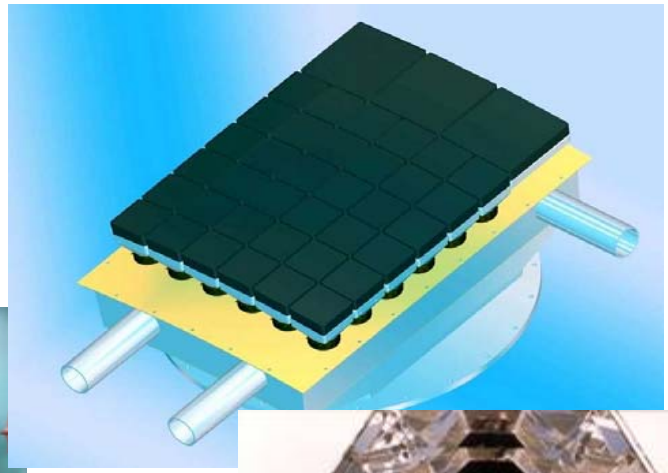
R&D Ongoing Projects (Heliostats)

In the **last five years several heliostats generation** have been developed with differents concepts of operation systems and differents sizes, always looking for cost minimizing. So the **prototypes Colon-70, Sanlúcar-90 and Sanlúcar-120** have been built.

R&D Ongoing Projects (Receivers)

Solúcar has also carried out projects to develop volumetric receiver for solar tower plants. The most important projects are:

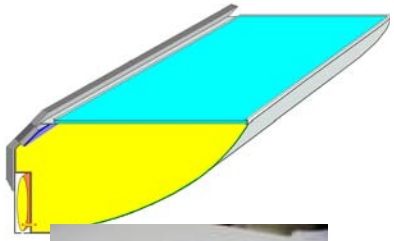
- **Sirec:** Volumetric receiver with wire mesh of 200 KWth.
- **Hitrec:** Volumetric receiver with ceramic matrix of 300 KWth.
- **Solgate:** Pressurized air receiver of 300 KWth.
- **Solair:** Ceramic matrix receiver of 3 MWth.



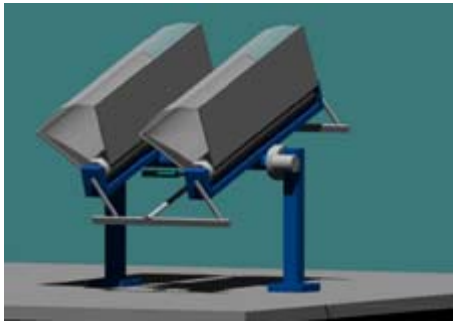
R&D Ongoing Projects (Photovoltaic)

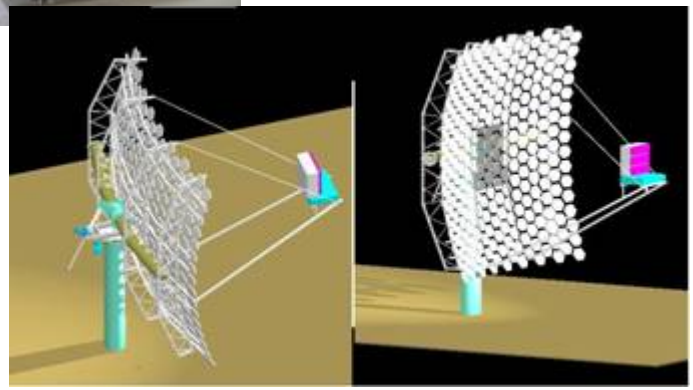
Other actual projects related to medium and high concentration photovoltaic are:

- **CAC:** European project for the implementation of a photovoltaic concentrator prototype in a controlled atmosphere with concentration ratio of 30X.
- **Hicon PV:** European project of high concentration (1000X).
- **Tilt Roll PV:** Heliostat prototype with movement "Tilt-Roll" for testing a commercial medium concentration module (21X).
- **Fresnel PV:** Fresnel Heliostat Prototype with concentration ratio of 5X, located at Aznalcollar.







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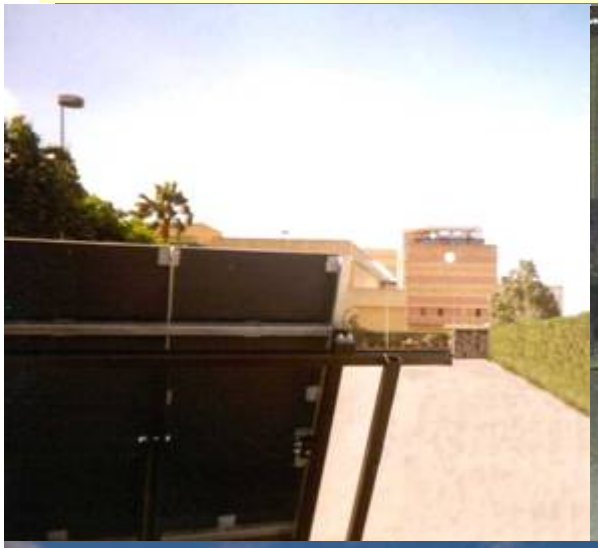
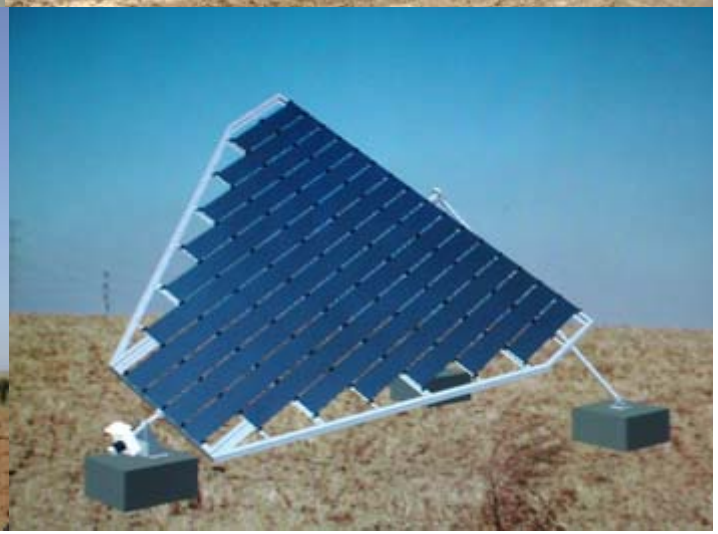
Compounds Supply

During the last two years**, facets** have been **manufactured and supplied**, for the Plataforma Solar de Almería and the Weizmann Institute.





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Promotional Demonstration Projects

All of this developments have concluded in two promotional **Demostration Projects** which are actually under construction and operation:

- **PS10 and PS20:** solar towers plants of **11 MWe and 20 MWe** with saturated steam receiver.
- **Sevilla PV:** photovoltaics heliostats plant with 2 axis tracking system and double concentration 2X of **1,2MW.**

Both projects are located in Casaquemada in Sanlúcar la Mayor (Sevilla).

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PS10 and Sevila PV (Jun 2006)

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Strategic Plan 300MW

Abengoa, Strategic Solar Plan

		2004				2005				2006				2007				2008				2009				2010				2011				2012				2013			
	MW	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T	1T	2T	3T	4T
Sevilla PV	1,2																																								
Sanlúcar Solar	10																																								
PS20	20																																								
AZ20	20																																								
Solnova 1	50																																								
Solnova 2	50																																								
Solnova 3	50																																								
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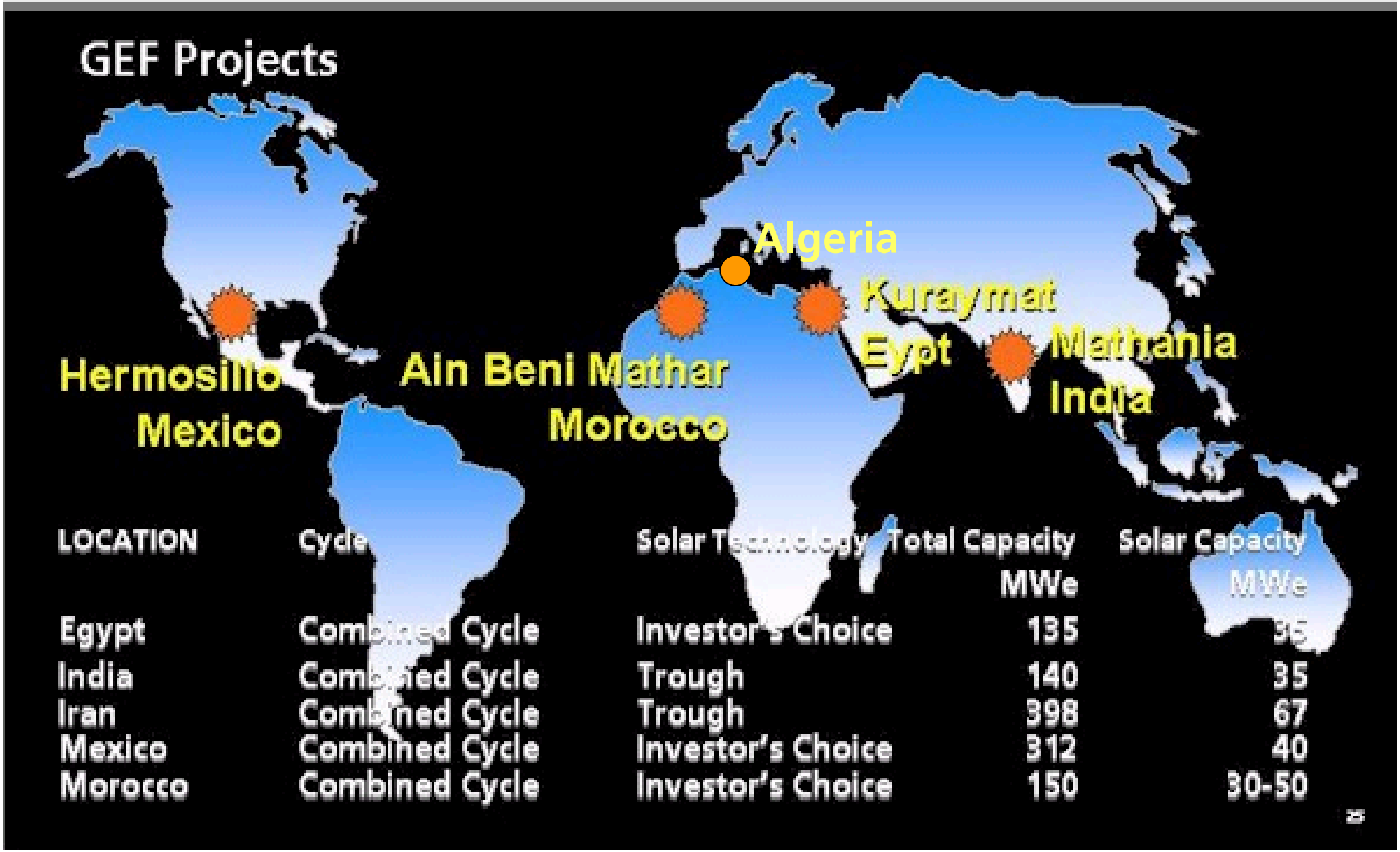
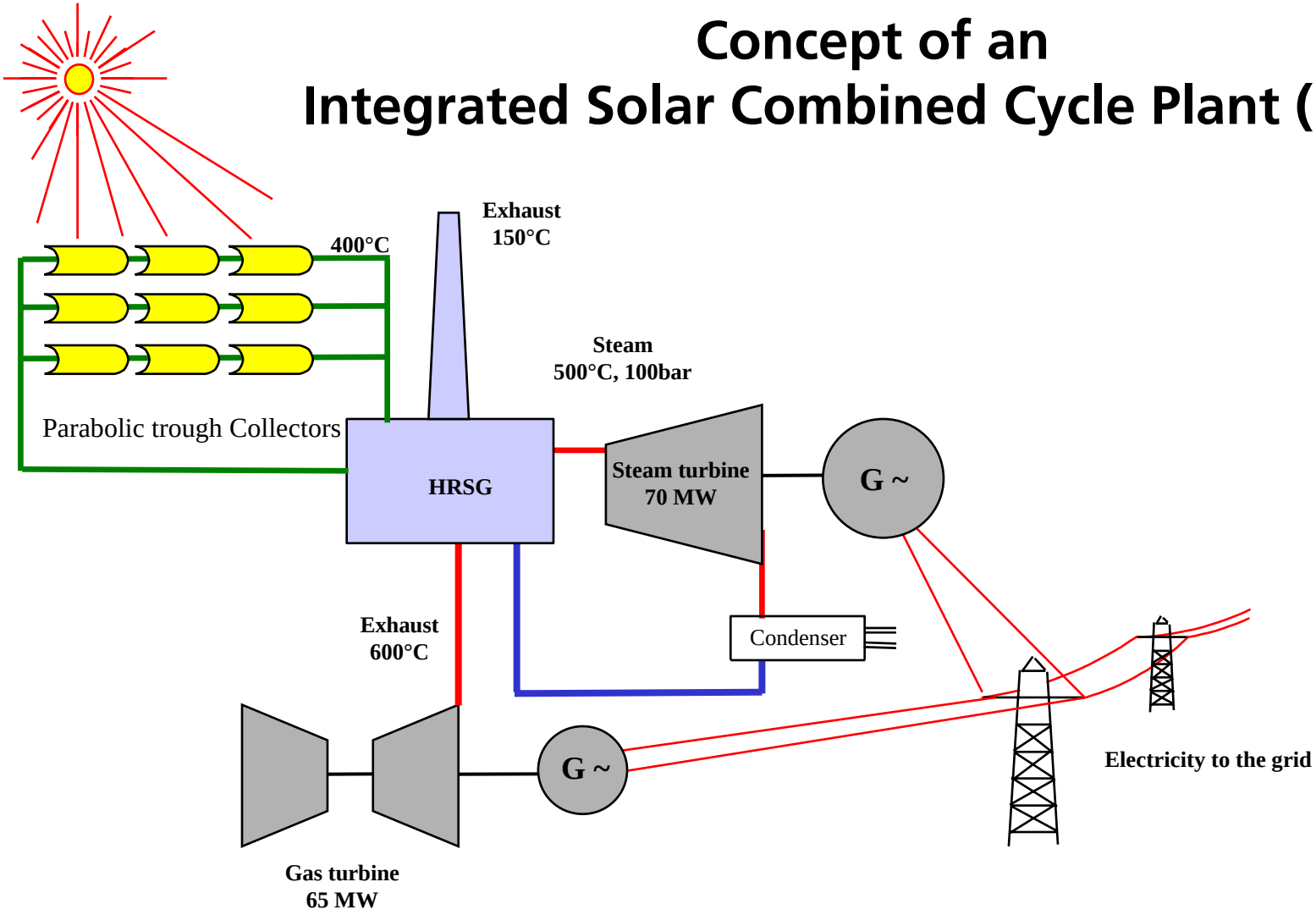


LOCATION	Cycle	Solar Technology	Total Capacity MWe	Solar Capacity MWe
Egypt	Combined Cycle	Investor's Choice	135	35
India	Combined Cycle	Trough	140	35
Iran	Combined Cycle	Trough	398	67
Mexico	Combined Cycle	Investor's Choice	312	40
Morocco	Combined Cycle	Investor's Choice	150	30-50

Concept of an Integrated Solar Combined Cycle Plant (ISCC)



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PS10

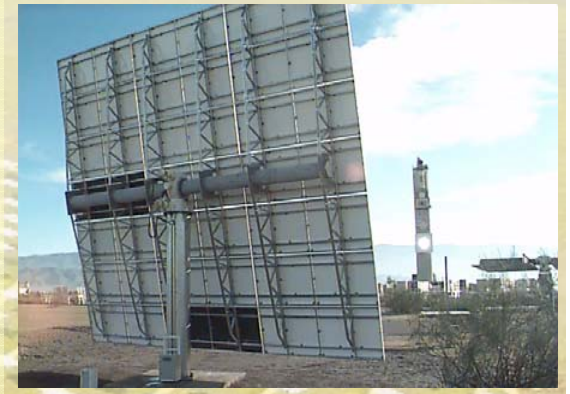
11MWe Solar Thermal Power Plant in Seville, Spain

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The Birth of the Project

1999 2000 2001 2002 2003 2004 2005 2006

- Recent publication in Spain of Royal Decree 2818/98 in Dec 1998, solar tariff (0,18€ + pool) to kWh
- As a continuation of a very early initiative of Sodean, Sol-Gas project in 1996, Inabensa (Abengoa company for solar electricity in 1999), had been later involved in Colón Solar project, an ISCC tower plant promoted by Sevillana (local utility) in 1997, and had acquired some know-how on heliostats manufacture
- As Colón Solar doesn´t success, Abengoa proposes an own project in 1999. It is PS10 (Planta Solar 10MW). Inabensa looks for a technology in receivers, in Solar Two (USA), and in Plataforma Solar de Almería, (Spain), and founds reliable TSA technology, (volumetric air wire mesh receiver), in operation since 1996. The technology is in BBP, (Babcock Borsig Power) that had recently acquired Steinmüller, a boiler company that had developed TSA. Mr Hans Fricker is contacted for advisory to Inabensa in the volumetric wire mesh technology as being the father of the tchnology



Colón Solar 70m2 Heliostat

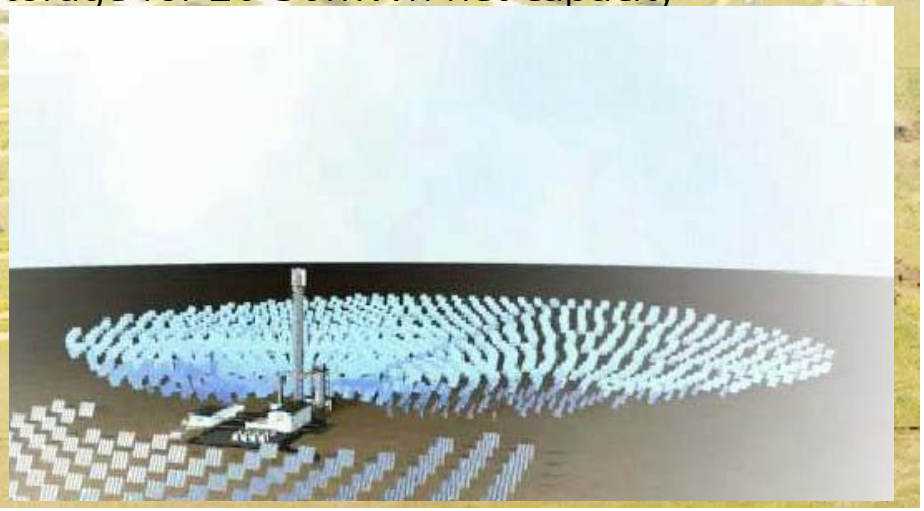
TSA Receiver in PSA

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The Birth of the Project

1999 2000 2001 2002 2003 2004 2005 2006

- **Inabensa prepares together with Ciemat, DLR and Fichtner a proposal to 5th FP of EC, Mr Manuel Romero is the father of the proposal, that is awarded with 5,0M€ subsidy to support PS10, a 35,0M€ project.**
- **Objectives for PS10 project:**
  - Construction of a 10MWe solar tower plant for operation under commercial basis
  - Validate electricity production over 20GWh/year(net)
  - Validate investment costs in the range of the 3000€/kW(gross)
  - Validate mass production of about 80.000m2 of heliostats with cost of 140€/m2
  - Validate a receiver technology (air) for 55MWt input power
  - Validate thermocline ceramic pebbles thermal storage for 20-30MWh net capacity
- **The project is presented to Andalucía Autonomic Government and is granted with an additional 1,2M€ subsidy**
- **By late 1999 Inabensa is informed that, because of a previous regulation to RD2818/98, a law allows only solar tariff of (0,18€ + pool) to the electric kWh for solar PV. No tariff is then considered for solar thermal electricity**



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PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The First Difficulties

1999 2000 2001 2002 2003 2004 2005 2006

- PS10 project officially starts for EC in Jan 2000, 36 months duration, till Dec 2002
- Because of the solar tariff lack for solar thermal installations, immediately it is requested to EC a postponement of 18 months for the project stating date, because of ´force majeure´ reasosn
- In parallel, activities for PS10 continue, never stopped
- Permiting activities advanced, grid connection, industrial use for land, regimen special, use of water, etc…
- Regarding technology Solúcar develops with co-finantiation of Spanish Government a bigger heliostat (Sanlúcar 90), and begin to incorporate volumetric air receivers technology with the collaboration of DLR, Ciemat, and the Themodynamics Group of Escuela Superior de Ingenieros de Sevilla in the ceramic technology with Hit-Rec programme, and in the metallic absorbers technology with SiRec programme
- Another R&D project on volumetric ceramic receivers, Solair, is found as elegible for EC 5th FP economical contribution. Inabensa coordinates this project, know-how on specific ceramic technology is from DLR, Mr Bernhard Hoffschmidt

Hit-Rec II 300kWt Receiver

Sirec 300kWt Receiver

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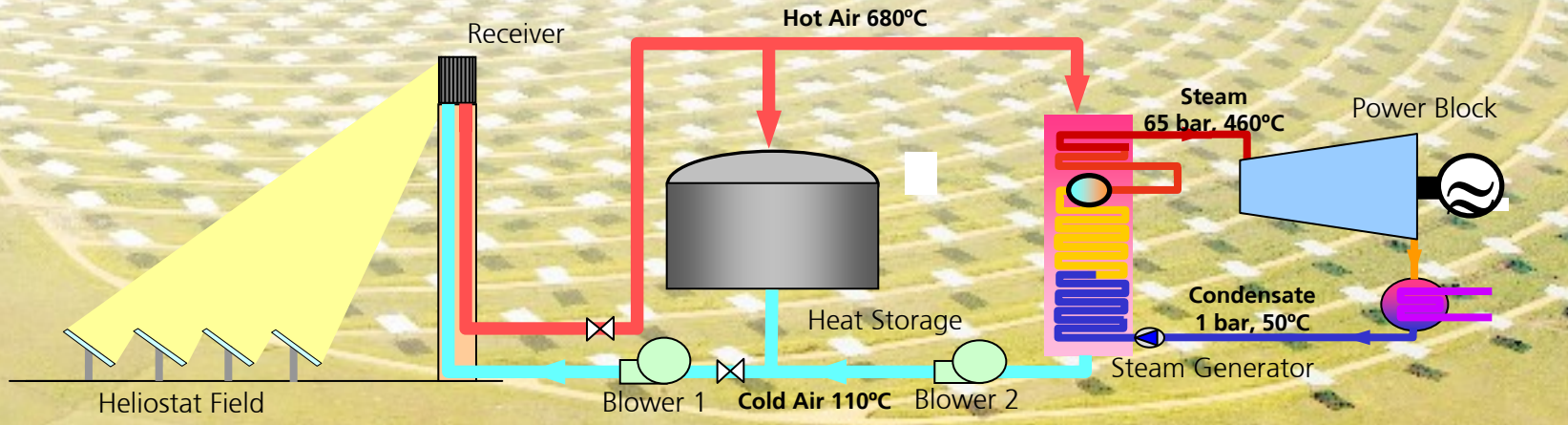
PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

Advancing without a Clear Horizont

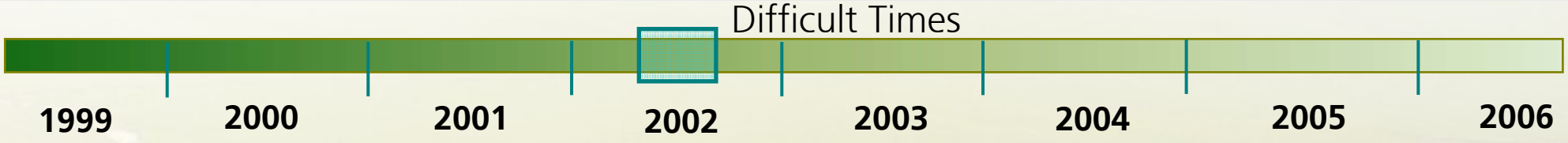
1999 2000 2001 2002 2003 2004 2005 2006

- By 2001 PS10 project is mature. It is composed by a 981 heliostats 90m2, and a volumetric wire mesh air receiver
- A detailed offer is contracted to BBP for the whole receiver technology, including blowers, heat storage system, and steam generator. A 9.6M€ budget is estimated by BBP. Mr Manfred Schmidt-Goeb is in charge of these works at BBP at Gummersbach
- R&D is done by Inabensa in order to improve cost-efficiency parameters for the thermocline selected storage system



- There is no solar tariff. Lobby is made by some groups on Spanish Government, Mr Manuel Blanco Director of PSA. No immediate response is obtained, at least at 2001

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain



- Abengoa decides to give more importance to the solar activities and creates Solúcar as the company responsible for the solar bussines from the Solar Group of Inabensa
- By August 2002 Spanish Government is finally sensible to the solar thermal pressure and publishes a tariff of 0,12€ per kWh. It does not seem enough but it is received as a temporal solution for many companies and projects
- PS10 project is the re-launched. A heliostat of 120m2 is developed to fit with new solar tariff. Updated offers are requested to suppliers, turbine, mirrors,…. Also updated offer is requested to BBP for the receiver system. BBP is in bankrupcy and has been judicially intervened. It is not possible for BBP to attend this demand
- Mr Schmidt-Goeb had finally ended in Shell for carbon gasification bussines, as it was his ordinary job in BBP. An offer is requested to Shell for this technology
- Solair R&D project is also advancing, and having good results. Solúcar has subcontracted to KAM the supply of the double membrane for the 3MW prototype, so KAM is in the position of making an offer to Solúcar for the receiver, heat storage system, steam generator and blowers. The work, that requires of previous enginering is contracted to KAM

Solair 300kWt Receiver

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The Light at the End of the Tunnel

1999 2000 2001 2002 2003 2004 2005 2006

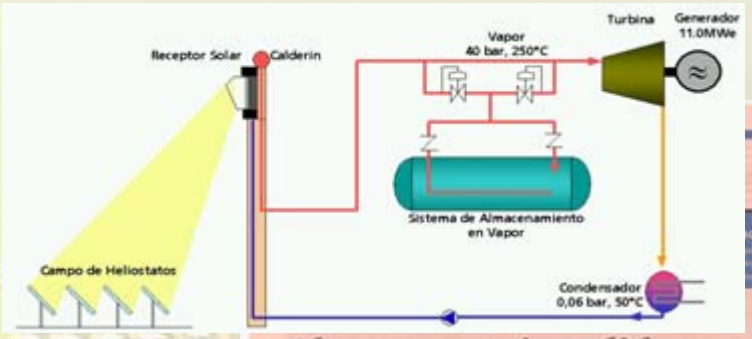
- Solúcar receives a good design work from KAM, but budget quotation for a total of 13,0M€ for the offered air volumetric ceramic system seems too high
- This offer, together to the low 0,12€/kWh solar tariff don´t allow PS10 project to reach economical feasibility
- Mr Rafael Olavarría, expert in power blocks and turbines of Abengoa joins Solúcar to help with this situation
- The proposal that had been defended by Proff. Valeriano Ruiz during long times for direct steam generation in the receiver of PS10 is presented to Olavarría. As hybridizing solar thermal with gas was not allowed in Spanish regulations by that time, no possibilities for superheating without technological risk were found. Finally, saturated steam generation in the receiver is detected as the optimal possibility to feed a saturated steam turbine
- Contact is established with Tecnicas Reunidas, Tecnical, the company that had manufactured the CESA-1 original steam receiver in the 1980´s, for a budget quotation for PS10 steam generation receiver. The company feels confortable with saturated steam and gives an offer for 6.5M€

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

With Favourable Wind

1999 2000 2001 2002 2003 2004 2005 2006

- A new design for PS10 plant is done based on new saturated steam receiver
- In Mar 04 Spanish Government increases tariff for solar thermal to original 0,18€ + pool. In Dec 04 up to 15% gas allowed
- The new tariff, the reviewed offers for the saturated steam technology and the disposability of all permits makes possible Financial Close with Sabadell bank.
- End of project in EC schedule is (considered 18 months postponement of starting date) 30th Jun 2004. An 18 months extension for the project execution is requested
- To support the new project extension an official groundbreaking event was hold at plant site, in Casaquemada, Sanlúcar la Mayor on 24th June 2004. The erection of the plant had started



PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The Construction

1999 2000 2001 2002 2003 2004 2005 2006

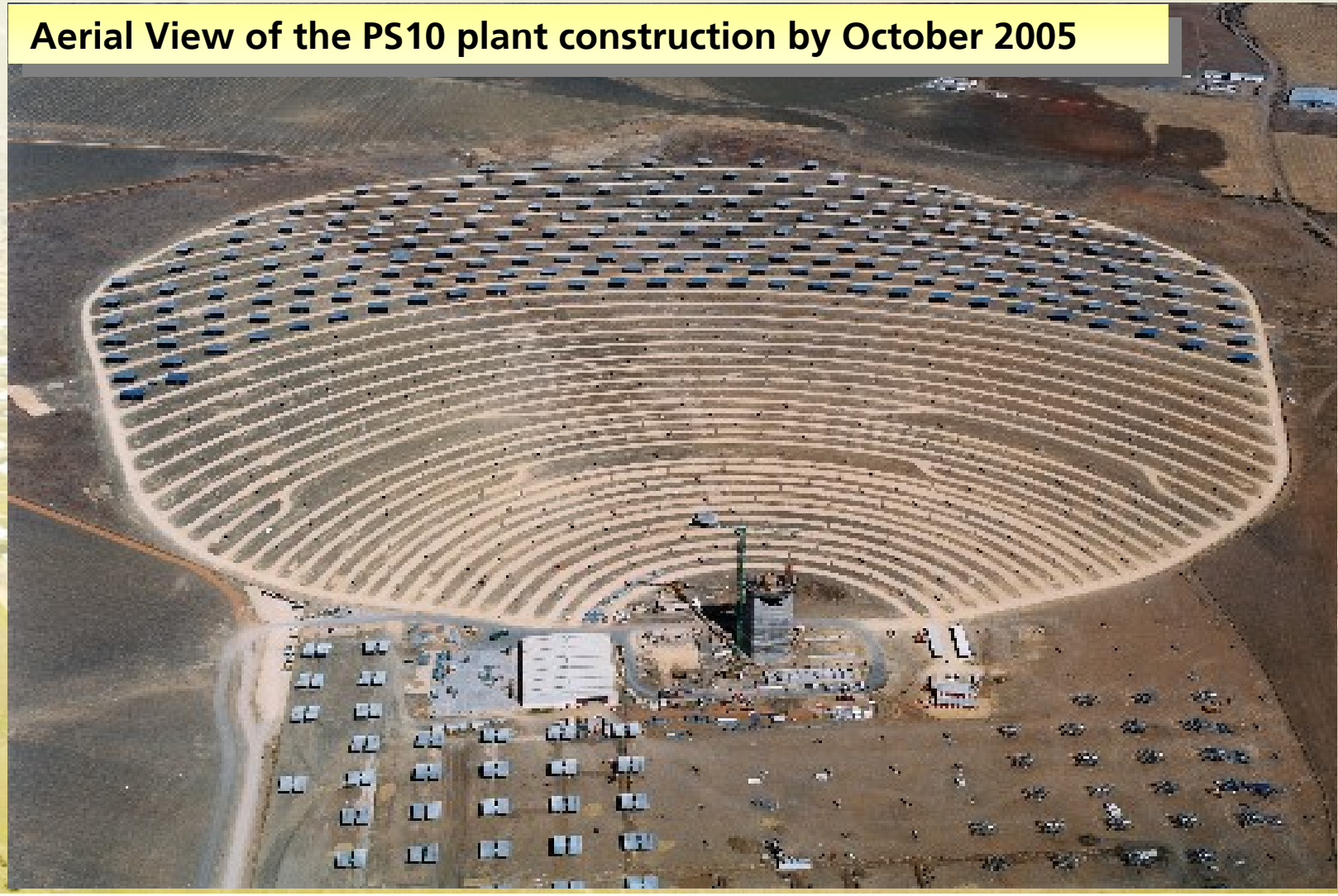
Aerial View of the PS10 plant construction by June 2005

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The Construction

1999 2000 2001 2002 2003 2004 2005 2006

Aerial View of the PS10 plant construction by October 2005

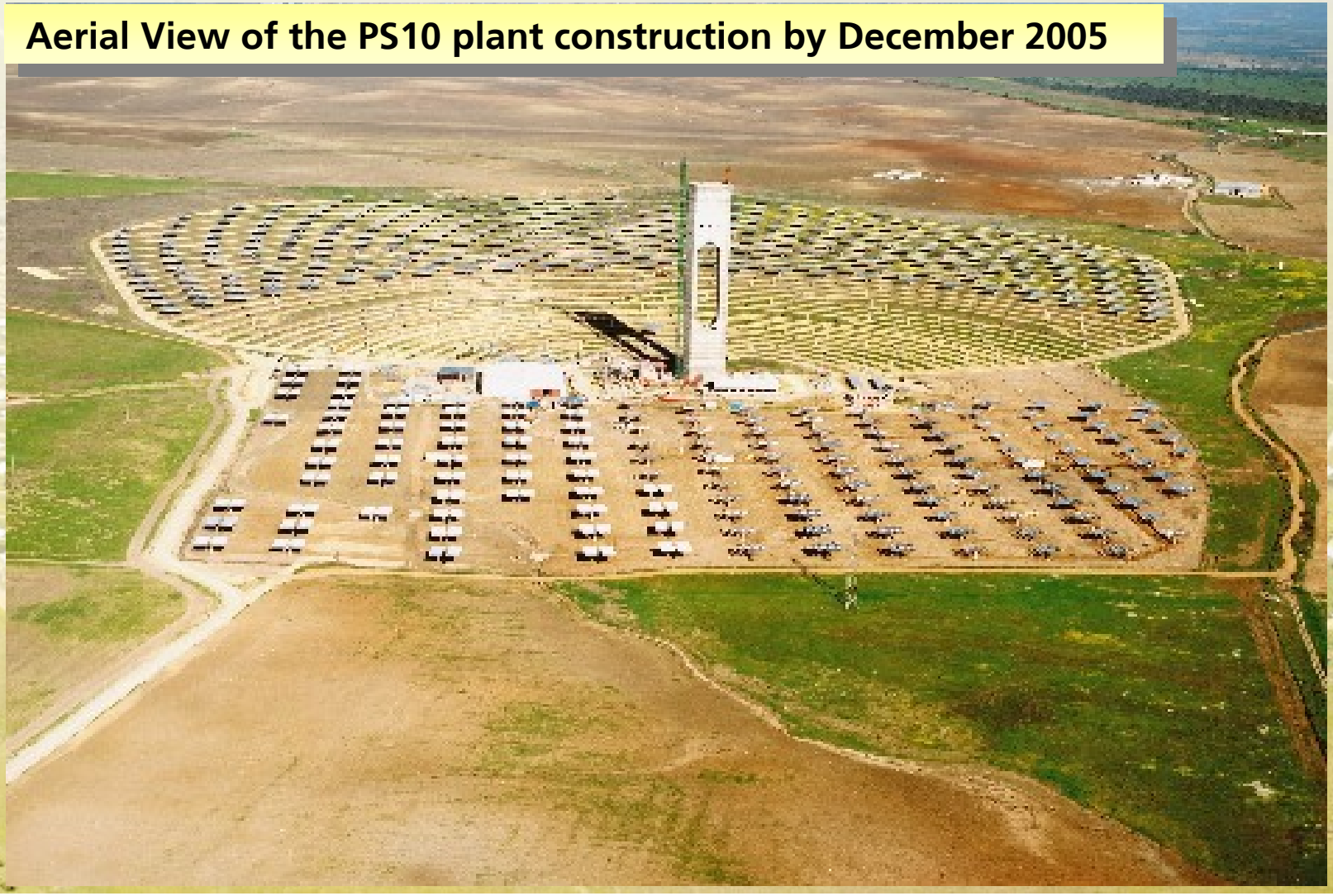


PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

The Construction

1999 2000 2001 2002 2003 2004 2005 2006

Aerial View of the PS10 plant construction by December 2005



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PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

Ending

1999 2000 2001 2002 2003 2004 2005 2006

PS10, heliostats testing, 2006

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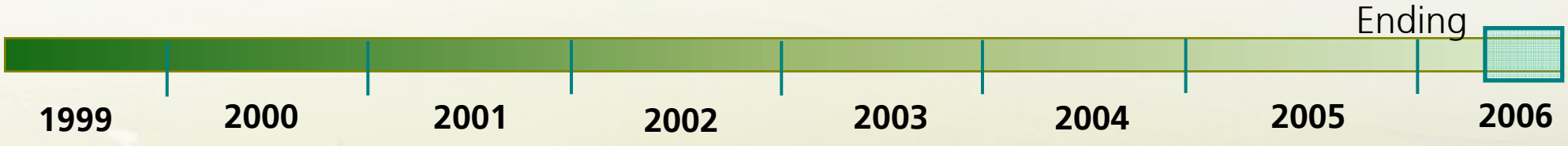
PS10, 11MWe Solar Thermal Power Plant in Seville, Spain



PS10, Assembly of Receiver Absorber Panels, April 2006

SOLUCAR R&D

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

Ending

1999 2000 2001 2002 2003 2004 2005 2006

Thermal Storage System and Refrigeration Towers

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PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

Ending

1999 2000 2001 2002 2003 2004 2005 2006

Saturated Steam GE Turbine and Steam Drum

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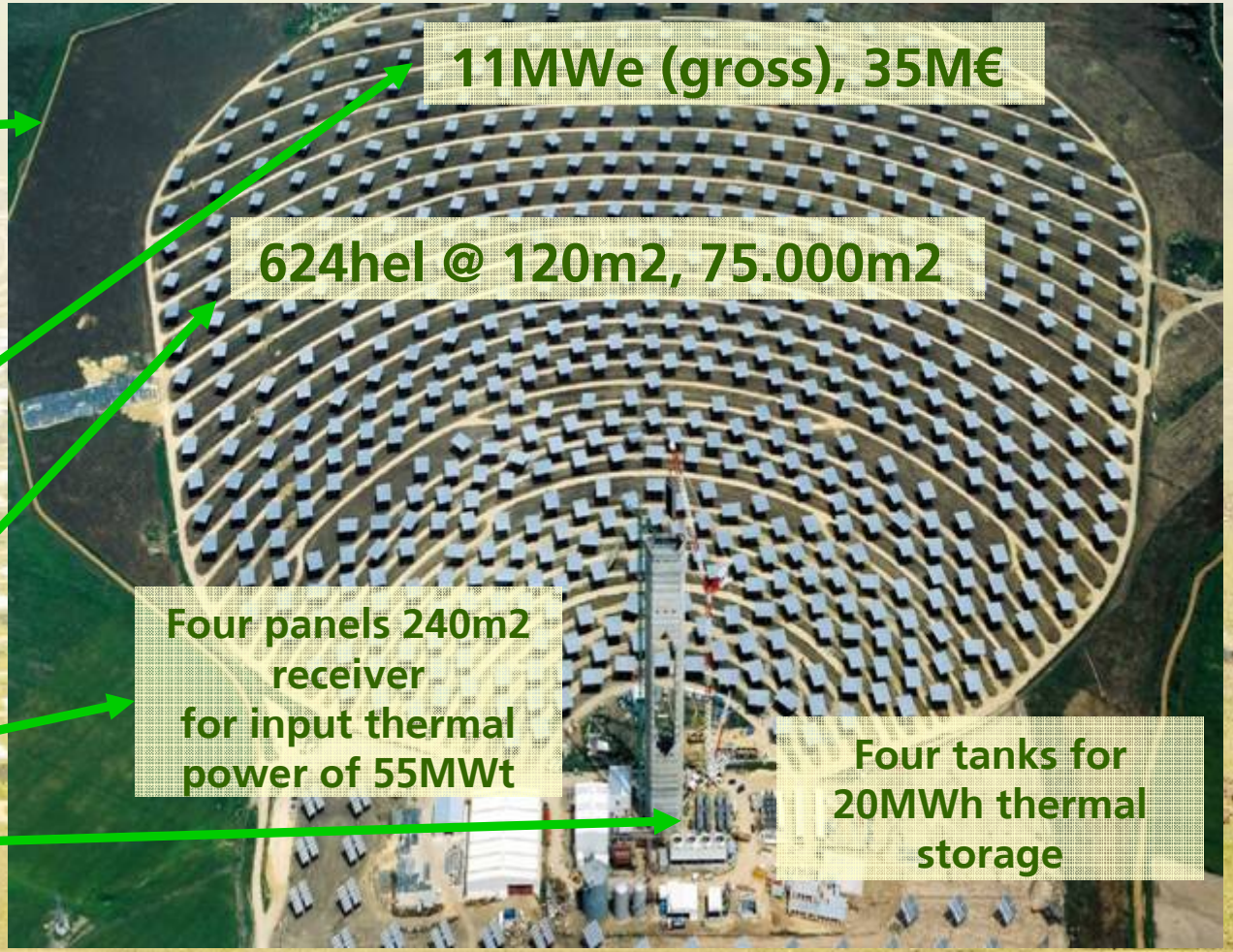
PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

Ending

1999 2000 2001 2002 2003 2004 2005 2006

- **Objectives for PS10:**
- Construction of a 10MWe solar tower plant
- Validate electricity production over 20GWh/year(net) **pending**
- Validate investment costs in order of 3000€/kW(gross)
- Validate mass production of about 80.000m2 of heliostats with cost of 140€/m2
- Validate a receiver technology (wet steam) for 55MWt input power
- Validate pressured water Ruths storage system for 20MWh net capacity



PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

SOLUCAR R&D

PS10, 11MWe Solar Thermal Power Plant in Seville, Spain

SOLUCAR R&D

PS20

SOLUCAR R&D

PS20

SOLUCAR R&D

PS20

SOLUCAR R&D

Thank you very much

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