Archimede Solar Energy

the new paradigm of the CSP Market




Company Structure

Strategic rationale

Chiyoda and FAL's expertise and resources will allow ASE to accelerate growth, reach its full potential and ensure its long-term success by joining an exceptional platform

Manufacturing Plant

Rceiver Tube

Demo Plant

Capital structure

Angelantoni Industrie — More than Technology

CHIYODA CORPORATION 千代田化工建設株式会社

فال القابضة FAL HOLDINGS

archimede solar energy

Shareholders

Angelantoni Industrie — More than Technology

Founded on 1932
Employees: 1,000 (Global Basis)
Revenue: €160Million (for 2011)
Fields: Testing, Life Science, Renewable Energy.

CHIYODA CORPORATION 千代田化工建設株式会社

Founded on 1948
Integrated Engineering & Construction
Employees: 7,000 (Global Basis)
Revenue: USD 3.2 Billion (for 2011)
Fields: petroleum, petrochemical, chemical.

فال القابضة FAL HOLDINGS

Founded on 1977
Employees: 4,000 (Global Basis)
Fields: Heavy Industries, Healthcare, Technology, Financial Services.

1 First producer of molten salts receivers

- ASE has a worldwide patent in an innovative CSP technology – molten salt receivers developed together with ENEA(1)
- Molten salt technology offers several advantages compared to oil:
  - Suitable for high temperature - more than 550°C
  - Lower volume required for thermal energy storage systems
  - No heat exchanger necessary in molten salt power plants
  - Much cheaper than synthetic oil
  - Environmental friendly / non-toxic / non-flammable

2 Diversified product portfolio

- ASE can produce receivers for all current technologies in the market: Oil, Molten Salt and Direct Steam Generation (DSG)
- ASE receivers for Oil technology have a better technical features against others
- ASE receivers offer a high Product Reliability in all technologies
- Flexible production process through a proprietary sputtering machine that can be easily tuned to produce different coating formulas according customer's request

3 275MW of projects

- Main projects located in Italy:
  - 4 in Sardinia
  - 1 in Sicily
  - 1 in Basilicata
- International projects located in China, California, New Mexico and Egypt

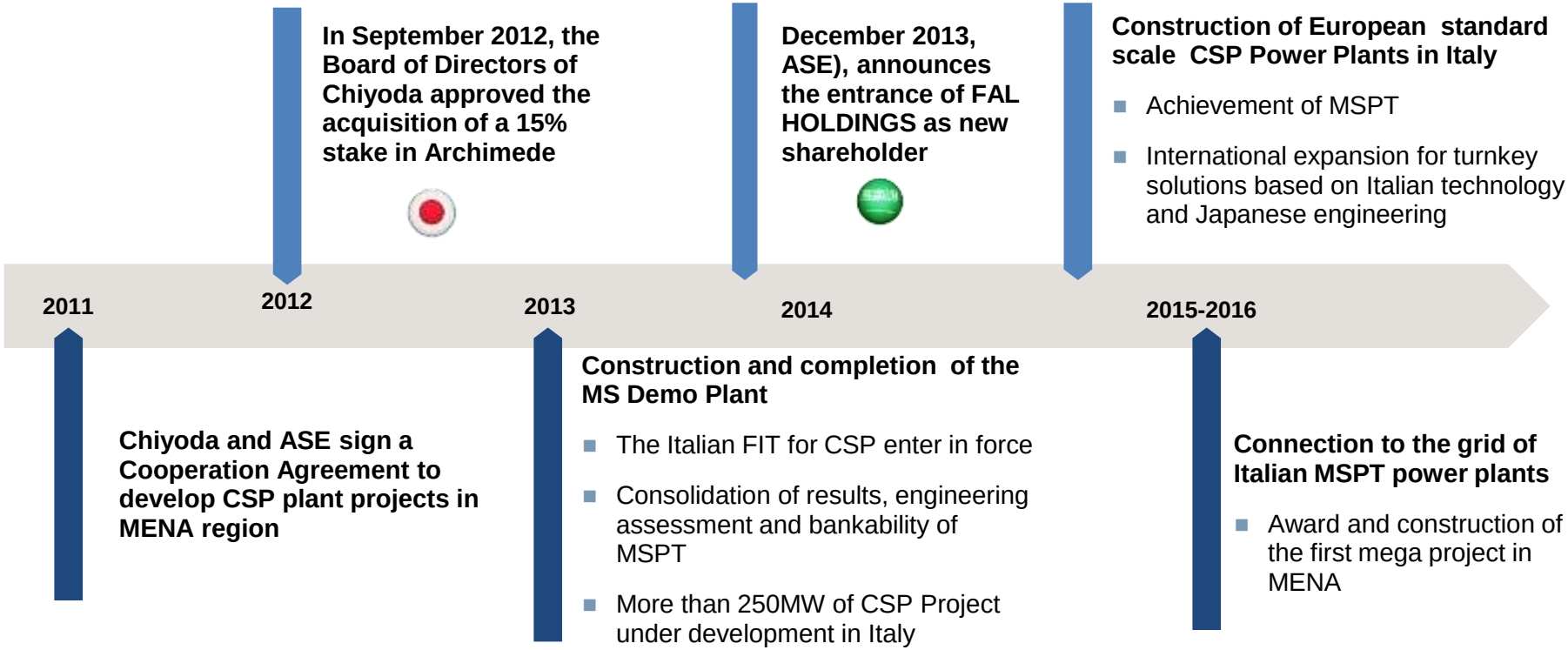
4 Strong strategic shareholder

- In September 2012, **Chiyoda** entered ASE's share capital
  - Chiyoda is a Japanese company engaged in integrated engineering
- *Chiyoda's expertise and resources will allow ASE to accelerate growth in selected markets and projects*
- In December 2013, **Fal** entered ASE's share capital
  - FAL is a Saudi conglomerate company engaged in several business fields with extensive relationship in Saudi Arabia.
- *FAL's expertise and resources will allow ASE to be a key player in Saudi Arabia. The world most important CSP market.*

(1) Italian National Research Agency for Renewable Energy.

Storyline and future perspective

Overview



Manufacturing Plant Overview

Archimede Solar Energy Demo Plant

the rationale of the project

Technology	To enhance the economy and reliability of parabolic-trough power plants using MS as HTF
Research	A focus for research oriented to the new frontiers of CSP
Bankability	Will provide data and reference for the financial closing of the commercial scale projects
Market	The demo plant is the LANDMARK of the upcoming Italian CSP Market
Divulgation	Sensitize National Institutions, popular committees, citizens about the real value proposition of CSP
Education	Customer, University, Students

Archimede Solar Energy Demo Plant

the rationale of the project

Since 2013 Archimede Solar Energy is operating the world most advanced concentrated solar power installation with thermal energy storage.

The demo plant represents the first stand alone Molten Salt Parabolic Trough Solar Plant located close to the ASE manufacturing facility in Massa Martana - Perugia (Italy).

It represents a powerful tool to perform internal testing in order to evaluate and demonstrate the improvements and innovations of Archimede Solar Energy receiver tubes.

The Demo Plant will provide a focus for research oriented to the new CSP frontiers and will be a benchmark of the Molten Salt Parabolic Trough performances and operating procedures.

It was built with Italian components and technology (ENEA Concept). The ASE Demo Plant aims even to be a showcase for the Molten Salt technology and the Italian supply chain.

Background:

Technology: parabolic trough collector using molten salt as heat transfer fluid
Location: Massa Martana - Perugia - Italy
DNI: 1550 kWh/m²/y
Installed capacity: 2 MWt
Electricity generation: 250 MWh/yr solar (2014)
Project type: Demo Plant

Plant configuration:

Nr. solar collector: 6 - (1 Loop) - 3600 m²
Heat transfer fluid: molten salt, binary mixture
Receiver tube: 144 Archimede HCEMS-11
Solar field outlet temperature: 550° C
Storage: 5hours - 50Tons

Participants:

Developer: Archimede Solar Energy
EPC: Chiyoda Corporation
Owner: Archimede Solar Energy

Land:

Area: 3 Hectares
Site ecology: Industrial area

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CHIYODA CORPORATION

ENEA
ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE

Manufacturing Plant
Production Capacity

- **Location**: Italy – Massa Martana (PC) Villa San Faustino
- **Starting Date**: September 14th 2011
- **Plant Area**: About 11.000 sqm of covered production area with additional 3.000sqm of adjacent offices. More than 30.000 sqm for all plant
- **Fully Automated and innovative manufacturing process**: the complete manufacturing equipment installed in the plant is based on internally-developed technology
- **Electric Equivalent production capacity**: 250 MWe/year
- **Net production capacity**: 75.000 rec/y (current) upgradeable up to 140.000 rec/y (as of in 2014)

Manufacturing Plant
Quality overview

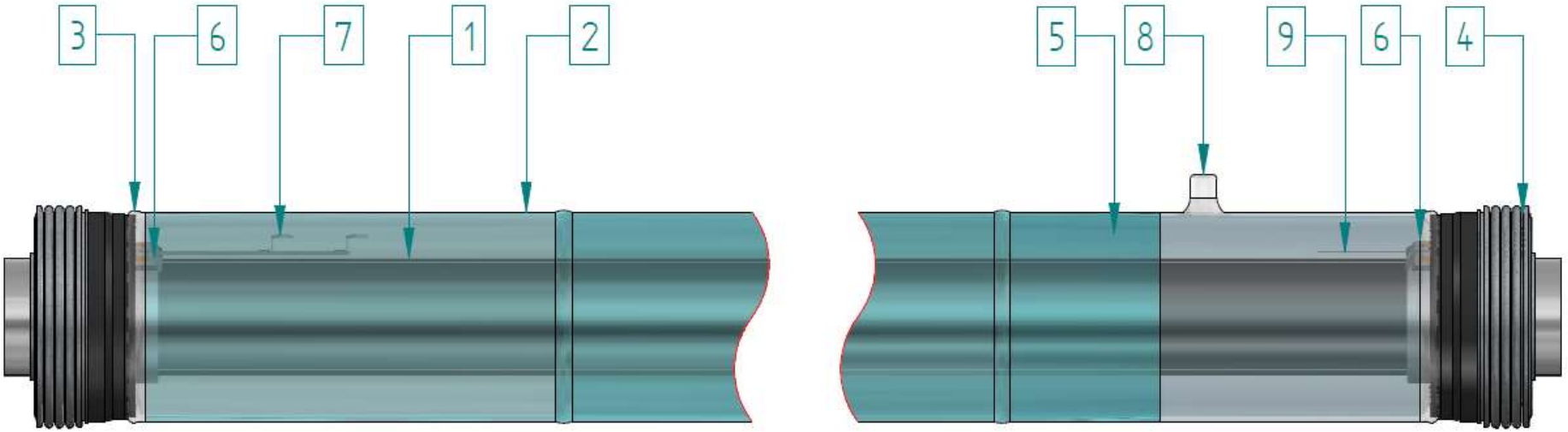
AREA - A

AREA - B

AREA - C

- Quality certified according to ISO 9001 standard since 2011.
- Internal and external quality check are continuously performed during production in order to ensure the highest quality levels.
- Internal test are performed with state of the art instrumentation as well as custom made tools when international standard are not applicable.
- Spectrophotometric analysis for absorbance and emissivity check.
- Metal collar oxidation quality.
- Bellows accelerated durability test .
- Glass metal sealing accelerated durability test .
- Metal welding quality.
- 100% leak test for glass metal sealing.
- 100% leak test for assembled receiver.
- 100% bellows leak test control.
- 100% degassing control (vacuum level and getter activation).
- AR deposition efficiency (glass jacket transmittance trough spectrophotometric analysis).

Product portfolio
Overview



1. Stainless steel absorber tube with spectrally selective coating
2. Glass jacket with Anti Reflective (AR) coating
3. Glass to metal seals
4. Thermal expansion compensators
5. Vacuum annulus
6. Not Evaporable Getter (NEG): pill (HCEMS-11, HCESHS-12, HCEOI-12)
7. Barium getter
8. Pump nipple
9. Serial number.

Product portfolio
Overview

- ASE's receiver tubes **maximize solar radiation absorption** and **minimize thermal losses**, reaching **temperatures up to 600 ° C** through a spectrally selective coating process, created and developed with ENEA
- The solar receiver tube consists of 2 pipes: the internal pipe is made of steel in which the HTF flows, while the external pipe is made of borosilicate glass. A **spectrally selective coating** (**CERMET**) is applied to the surface of the steel pipe to reach a high absorpting coefficient of the solar radiation and a low thermal emissivity, while the external glass has an **anti-reflective coating** on both surfaces to increase the solar transmittance
- Receivers already **qualified** by external laboratory, plant, test loop and test collector
- In 2011, **ASE has been certified according to ISO 9001**, as Quality Management System
- In 2013, **ASE products have been certified by Det Norske Veritas**

Molten Salt based CSP plants

- **Code Name**: HCEMS-11
- **Market Introduction**: 2008 (HEMS08)
- Unique receiver worldwide operating up to 550°C

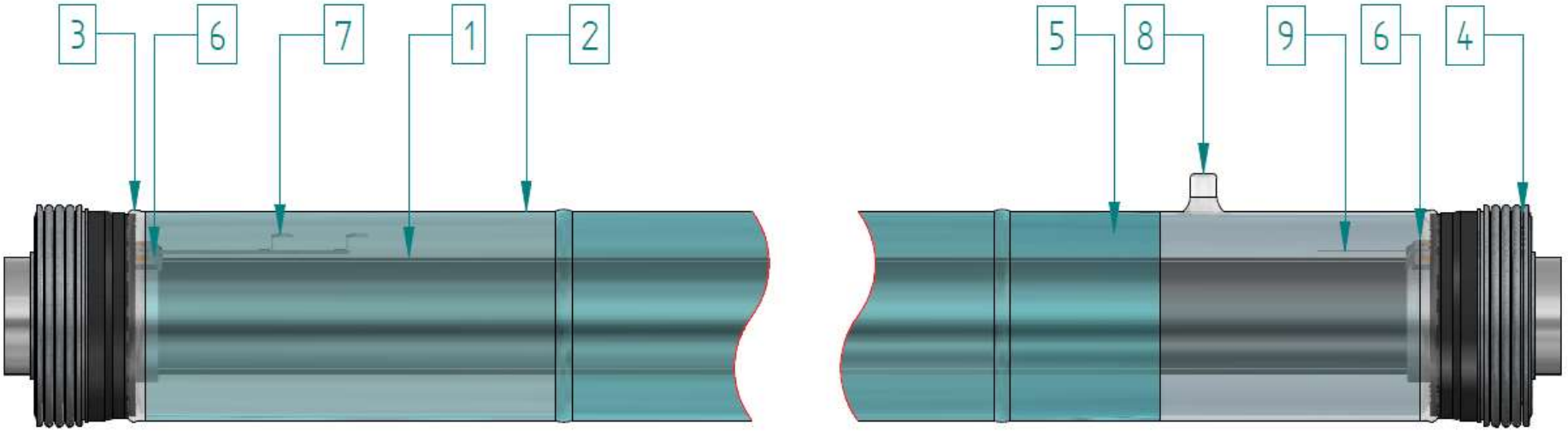
Oil based CSP plants

- **Code Name**: HCEOI-12
- **Market Introduction**: 2011
- Offering a high stability coating downgraded from the MS recipe

Direct Steam Generation CSP plants

- **Code Name**: HCESHS-12
- **Under test**
- **Market Introduction**: expected during this year
- Unique receiver worldwide operating up to 550°C and close to 100 bar

Product portfolio Overview



CERMET manufactured under ENEA's licence

Anti-reflective coating manufactured under CIEMAT's license

Glass to metal seal patented by ASE

ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

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Laboratory qualification
ENEA, DLR and Ciemat

ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

DLR Deutsches Zentrum für Luft- und Raumfahrt

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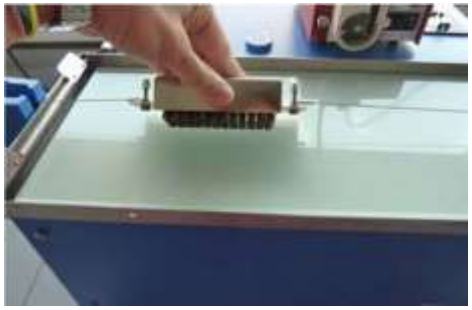


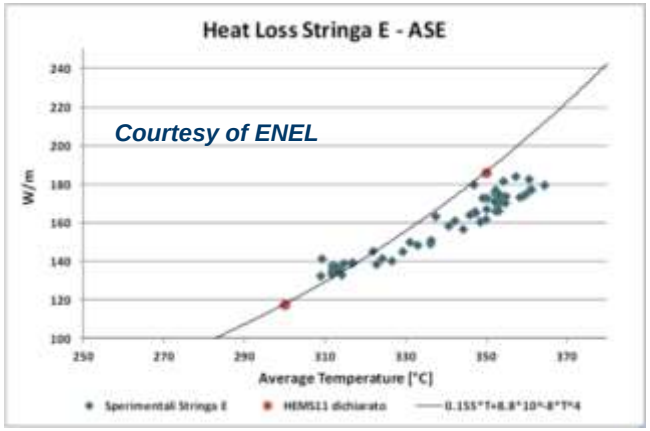
Plant, test loop and test collector qualification

Italy, Spain, USA

Italy

ENEL Archimede 5 MWe ISCC – MS Parabolic Trough Plant

- **HTF**: 60-40% $NaNO_3$-KNO_3
- **Status**: Operation
- **Since**: June 2010
- **NoT**: 290÷550 °C
- **Note**: Over 6000 hours of operation in a commercial molten salt parabolic trough plant, with 2-tanks storage system



Italy

CHIYODA/ASE MS Demo Plant – MS Parabolic Trough Plant

- **HTF**: 60-40% $NaNO_3$-KNO_3
- **Status**: Operation
- **COD**: 2013
- **NoT**: 290÷550 °C
- **Note**: Over 2000 hours of operation in a complete molten salt parabolic trough demo loop, with 2-tanks storage system

Plant, test loop or test collector qualification

Italy, Spain, USA

Italy

ENEA PCS – MS Parabolic Trough Test Plant

- **HTF**: 60-40% $NaNO_3$-KNO_3
- **Status**: Operation
- **Since**: 2006
- **NoT**: 290÷550 °C
- **Note**: Over 1900 hours of operation in a collector test facility, with 1-tank storage system

USA

MS Compact Linear Fresnel Reflector

- **HTF**: 60-40% $NaNO_3$-KNO_3
- **Status**: Operation
- **Since**: COD 2014
- **NoT**: 290÷550 °C
- **Note**: First CLFR using MS as HTF

Spain

CIEMAT PSA – Oil Parabolic Trough Test Plant

- **HTF**: Oil
- **Status**: Test completed
- **Since**: 2012-2013
- **NoT**: Up to 400 °C
- **Note**: complete test report available