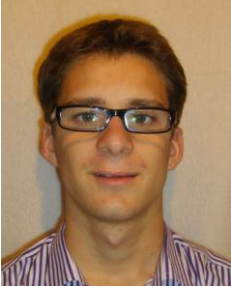




Modeling Linear Fresnel

Benoit Gourhand, Asst. Project Engineer
Simon Benmarraze, Deputy General Manager

07/23/2013



Benoît Gourhand

benoit.gourhand@solareuromed.com

Internship advisor : Simon Benmarraze, Deputy General Manager, Solar Euromed




- Assistant Project Engineer (intern), Solar Euromed, France.
- Assistant Engineer at the Solar Energy and Energy Saving Laboratory (LESEE), Ouagadougou, Burkina Faso.
- Academic backgrounds:
 - M.Sc., Energy Engineering, Polytech'Annecy-Chambéry, France
 - M.Sc., Energy Engineering, Universidad Politécnica de Madrid, Spain (Exchange Student)

Solar Euromed is a leader in CSP technology with innovative Linear Fresnel technology





The company markets innovative solutions using its proprietary Fresnel technology based on CSP direct steam generation providing turnkey solar steam boilers for power generation, and industrial applications.



Research, Development, & Innovation

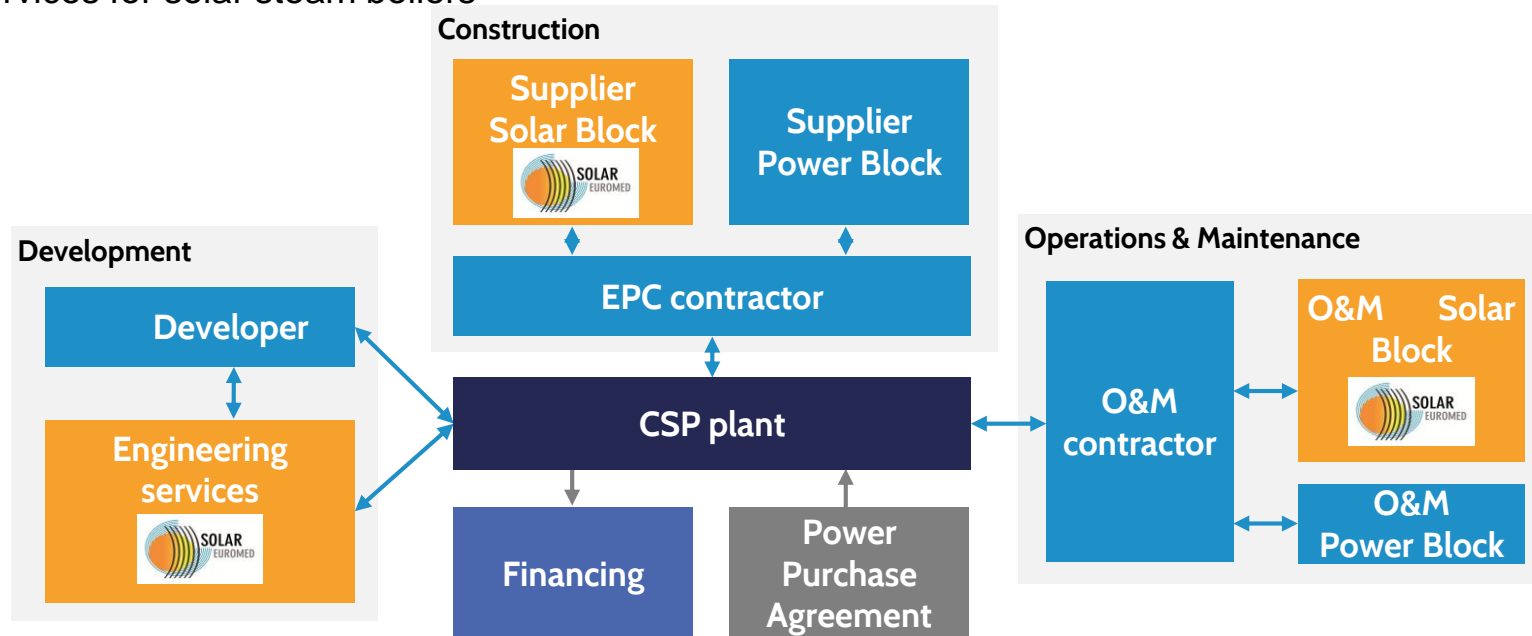
-  In 2007-2009, Solar Euromed has studied parabolic trough technology in details and gained inside knowledge in the environmental impact and cost reduction potential of this technology;
-  In 2009-2010, the Group launched its technology development plan co-funded by the French State which initially resulted in the commissioning of Augustin Fresnel 1, a Linear Fresnel pilot plant located in the South of France currently in operations.
-  In 2011-2012, Solar Euromed has formulated a R&D project called LFR500 set to develop a Fresnel collector capable of generating high-performance superheated steam at more than 500°C. The project has received financial support from the French State and is implemented since 2012.

Commercial Pipeline

-  In 2012, Solar Euromed has won the award for the largest CSP plant in France (Alba Nova 1, 12 MW in Corsica)
-  In 2012, Solar Euromed received financial support from the French Government for the implementation of a 3 MW solar thermal power plant in Tunisia in partnership with the Tunisian electric utility STEG.
-  In 2013, Solar Euromed was awarded the largest solar CSP project in the Kingdom of Jordan with NERC
-  For the period 2013-2017, the company has developed a pipeline of tangible projects totaling 370 MW in Southern Europe, Mediterranean, Africa regions to be implemented.

Solar Euromed supplies equipments and services at each stage of a CSP plant lifecycle

- Turnkey Supply of solar steam boilers with proprietary technology (solar field and thermal storage equipments)
- Engineering services (development, construction)
- O&M services for solar steam boilers



Solar Euromed has developed expertise in the design, development, and evaluation of innovative CSP technologies



2010-2012 : Augustin Fresnel 1, a solar thermal power pilot plant

- Solar Euromed implemented its landmark technology into a 250 kW pilot plant called Augustin Fresnel 1 and located in the French Pyreneans, at the Thémis technology platform.
- It was financed by Solar Euromed, with the support of OSEO, a French public innovation agency and the European Union.
- Augustin Fresnel 1 provides an experimental basis for the construction of future projects.



2012-2014 : LFR500, a Fresnel system generating steam at $> 500^{\circ}\text{C}$

- Solar Euromed is bringing innovations to the market, enabling to generate superheated steam at more than 500°C . Nowadays, such a high temperature can only be achieved in point-focusing devices, which have a much lower absorption area and therefore lower thermal losses.
- The LFR 500 module will be implemented in the hottest section of the future Fresnel solar fields, transforming saturated steam coming from the evaporating section into superheated steam.



Solar Euromed has developed a unique track record of successful commercial CSP projects

Alba Nova 1, France's largest innovative solar power plant

- Alba Nova 1 is the first utility-scale demonstration project in France in the field of Concentrated Solar Power (CSP) demonstrating an innovative CSP Fresnel technology with Thermal energy storage capability developed by Solar Euromed . Alba Nova 1 is backed by Caisse des Dépôts et Consignations, the French public sovereign fund and obtained a 20-year tariff obtained on a competitive basis through a national tender issued by the French Government and a guarantee over annual production provided by a recognized EPC contractor.



Jordan WECSP, Middle East's first Linear Fresnel CSP plant connected to the Grid.

- Jordan WECSP operated by the Jordanian Energy Research Center is the first utility-scale Linear Fresnel CSP power plant in the Middle East. SOLAR EUROMED was able to meet the project's objectives and will implement its technology in this pioneering project in the Middle East. Such initiative highlights the value delivered by LFR technology and serves as an example for the anticipated deployment of CSP technology in the Kingdom of Jordan and the Middle East.



Linear Fresnel Modeling

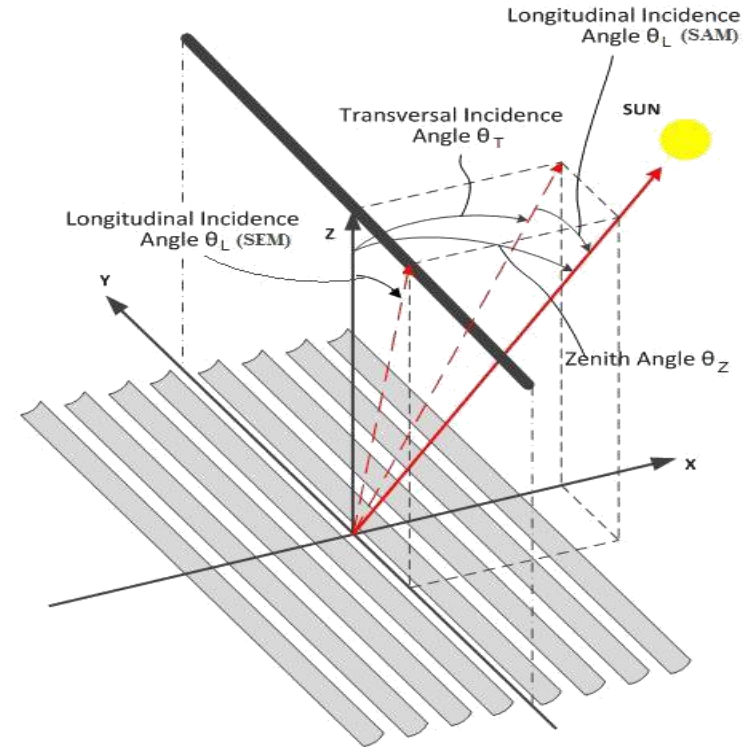
SAM is a relevant tool for Linear Fresnel plant modeling but requires further adjustment to fit with this technology.

Advantages

- Recognized software
- Comprehensive optical and thermal modeling

Limitations

- Applicable only for superheated steam
- No Turbine load curve modification
- Limited storage modeling



Source: Results and Comparison from the SAM Linear Fresnel Technology Performance Model, May 13, 2012 (Michael J. Wagner)

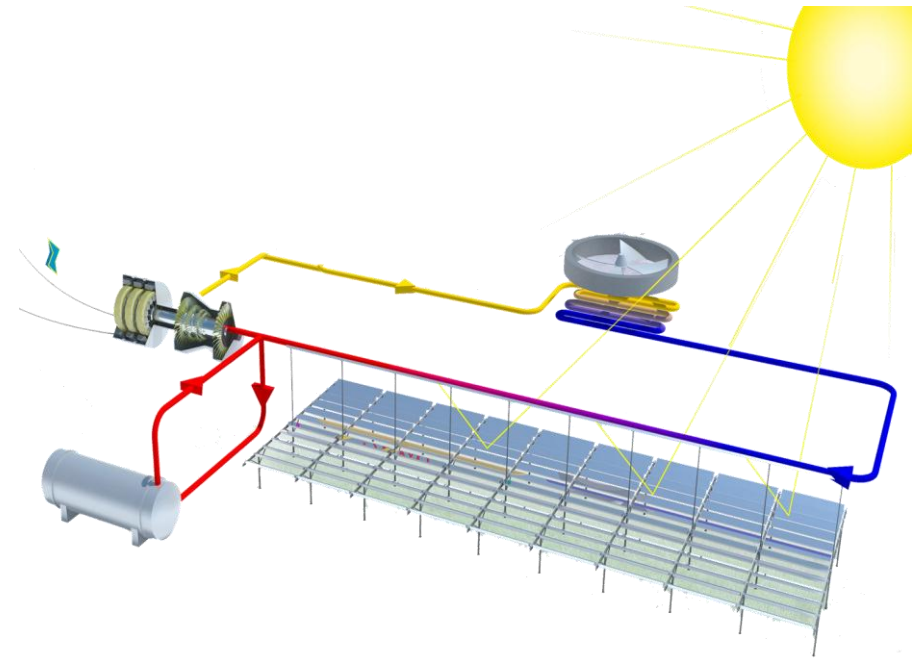
Solar Euromed has developed an in-house software that fits with its technology requirements

Advantages

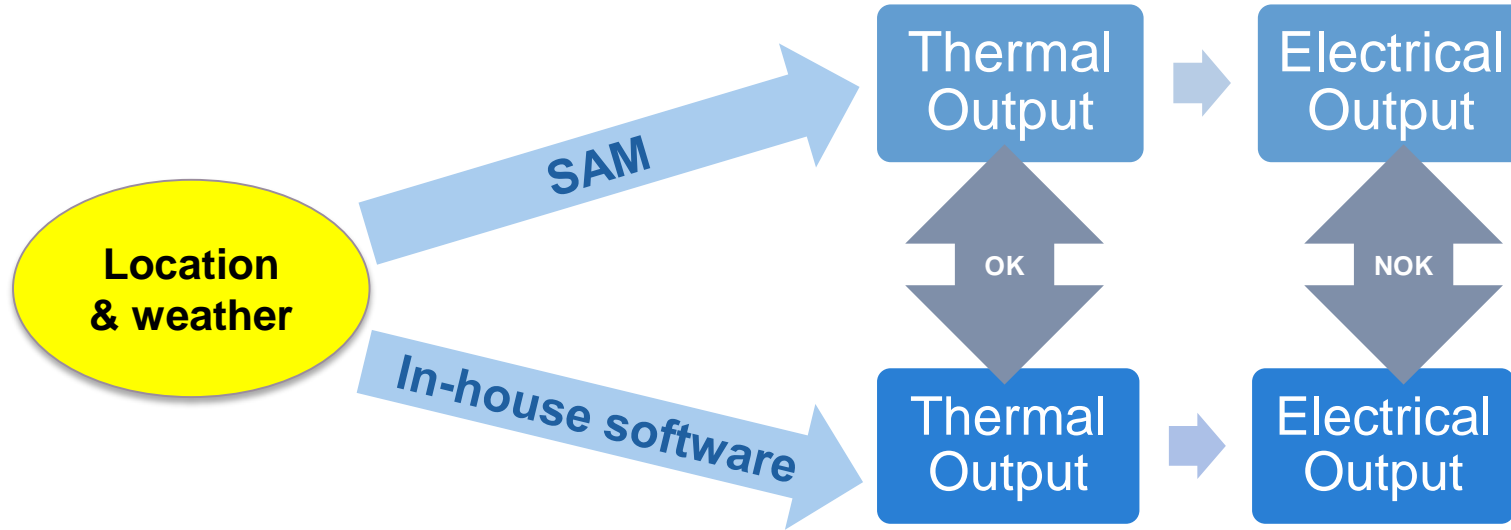
- Adapted to Solar Euromed's technology
- Cogeneration and renewable steam design capacity
- Design flexibility (cycles, load curves, equipments, etc...)

Limitations

- Limited application for other CSP technologies (tailored-made for Solar Euromed)



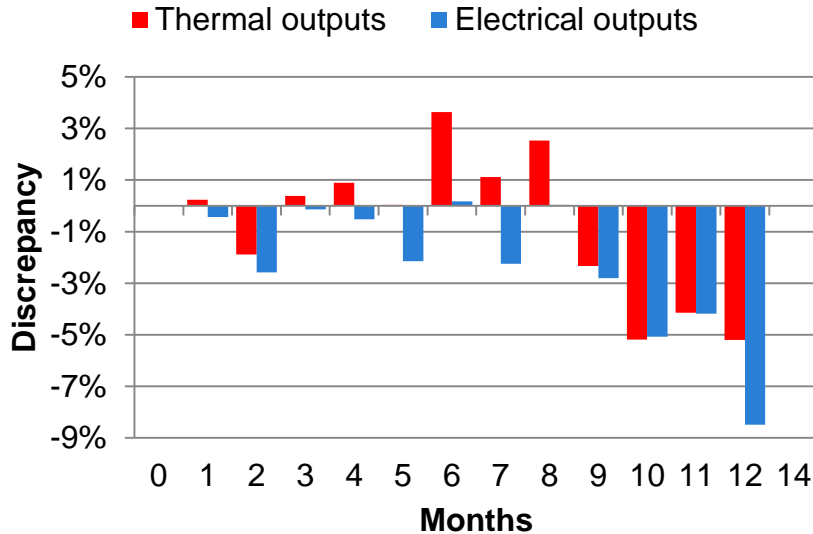
SAM and Solar Euromed's in-house modeling software have very close thermal outputs. Both modeling cannot be compared though for electricity generation outputs



- **Similar thermal output** (using a once-through loop)
- **No direct electrical simulations with SAM**
 - Generate an electrical output with our in-house software
 - The implement it in SAM with the option *Generic System* to do the economic analysis

Source: Results and Comparison from the SAM Linear Fresnel Technology Performance Model, May 13, 2012 (Michael J. Wagner)

Annual and monthly analysis highlights low discrepancies between softwares



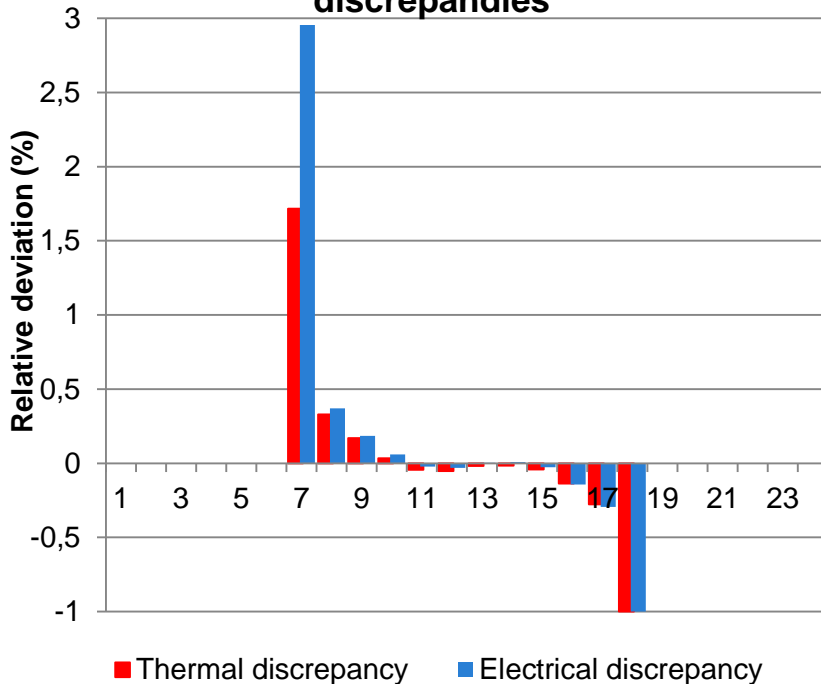
Annual discrepancies are **under 3 %** for every case study

Comparisons were executed on very different case studies (DNI, power and pressure)

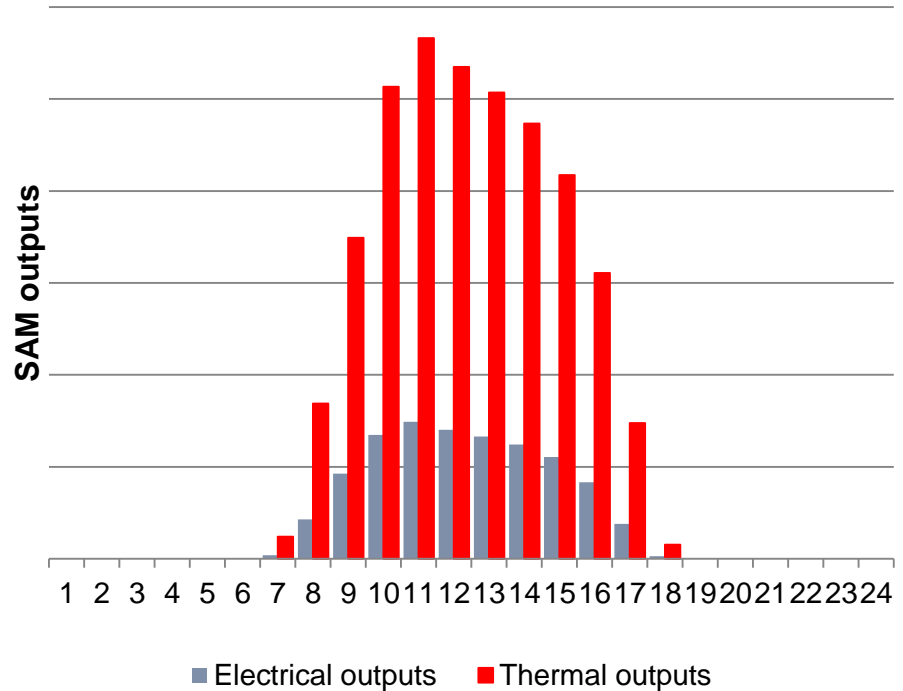
	AN1 (12 MW)	AN1 (24 MW)	Daggett (2 MW)	Daggett (16 MW)	Tunis (12 MW)	Tunis (160 MW)
Thermal Production	- 0,4%	1,5%	- 1%	2%	- 0,2%	- 0,5%
Electrical Production	- 1,6%	1%	- 0,5%	2,4%	- 1,4%	- 1,4%

Good match for daily average thermal and electrical outputs. Low impact discrepancies during dawn and sunset.

Daily thermal and electrical discrepancies



Daily thermal and electrical outputs (SAM)



Good match between SAM and Solar Euromed results for thermal outputs based on similar inputs

- Discrepancies lower than 3 % for every case study
- Usable daily, monthly and annual simulation outputs
- Daily deviations mainly during startup and sunset
➔ low analysis impact



Improvement suggestions :

- ✓ Modifiable turbine load curve
- ✓ Storage
- ✓ Saturated steam models
- ✓ Combined heat and power models

See you at SolarPACES 2013 !



Solar Euromed's 2013 Contribution to SolarPACES Las Vegas Edition	Type
Acceptance Testing Procedure for Linear Fresnel Reflectors solar systems in utility-scale Solar Thermal Power Plants	Paper
Modeling the socio-economic impact of the development of the CSP industry in a national and international context: Assessment of Job Creation and GDP contribution	Paper
Advantages of Linear Fresnel Reflectors Technology in the context of the development of solar power in a Middle East country	Poster
Tracking and motorization system for Linear Fresnel Reflectors technology: performance enhancement and cost reduction methods	Poster



Contact :

Simon Benmarraze
Deputy General Manager

Email : simon.benmarraze@solareuromed.com

Copyright Solar Euromed
2013 All Rights Reserved