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# Experimental and theoretical evaluation of heat losses from a solar receiver in a 9 MWe commercial power plant using linear Fresnel concentrator

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## Research project context

### Modeling and optimization of the eLLO direct steam generation solar power plant with a steam storage system

Inaugurated in 2019 by SUNCNIM; Operated by ELLO; Located on the Cerdan plateau, Pyrénées Orientales (66), France

## Introducing the eLLO solar power plant

### Solar field :

- 27 parallel solar lines made up of 4 to 8 linear Fresnel modules assembled in series; total collector area of approx. 153 000 m<sup>2</sup>,
- Operating pressure and temperature: 70 bar; 286°C,
- Solar field with direct steam generation; flow control to ensure a theoretical steam quality of 80% at line outlet,
- Cavity solar receiver positioned 8.5 m above the mirror axes,
- CPC-type secondary reflector.



Figure 2: Photo of the eLLO solar power plant

### Steam storage system :

- 9 parallel tanks of 120 m3 each for a maximum load equivalent to 4 hours of production at full power, → World premiere
- Sensitive energy storage in the form of pressurized water.

### Power block :

- Hirn thermodynamic cycle,
- 9 MWe superheated steam turbine,
- Dry air condenser and thermodynamic superheater.

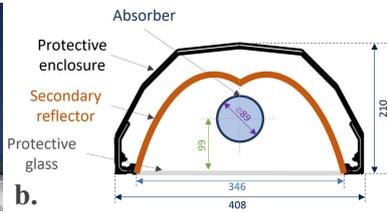


Figure 1: (a.) Photo of the receiver and (b.) Dimensions of the solar receiver in millimeters

## Experimental protocols & calculation methods

- Two experimental protocols make it possible to evaluate the heat loss of the eLLO solar receiver at different temperatures without impacting electricity production,
- These protocols allow fluid to circulate in 3 instrumented solar lines, without concentrating solar radiation towards the receiver,
- The low-temperature protocol (50 to 150°C) operates in a transient flow regime, while the high-temperature protocol (150 to 250°C) operates in a steady-state flow regime,
- Receiver heat losses are calculated using the receiver/fluid heat balance (equation (1)):

$$m_{abs} \cdot \frac{dh_{abs}}{dt} + m_f \cdot \frac{dh_f}{dt} = \dot{m}_f \cdot h_{in}(t) - \dot{m}_f \cdot h_{out}(t) - P_{loss}(t) \quad (1)$$

- Considering a steady state, i.e. when the inlet and outlet fluid temperatures are constant, the absorber inertia is zero and equation (1) simplifies as follows:

$$P_{loss,steady-state}(t) = \dot{m}_f (T_{in}(t) - T_{out}(t)) \quad (2)$$

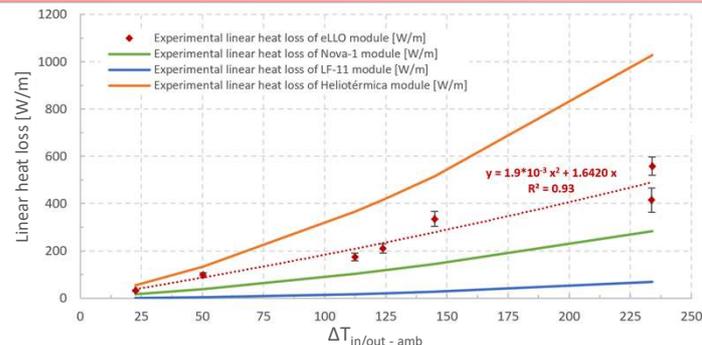
- For a transient regime, the heat balance terms of the solar receiver (equation (2)) are integrated over the study period, and the inertia of the system is approximated by considering the energy variation of the fluid and the absorber tube.

$$\int_{T_1}^{T_2} m_{abs} \cdot C_{abs} \cdot dT_{abs} + \int_{T_1}^{T_2} m_f \cdot C_{p_f} \cdot dT_f = \int_{t_i}^{t_f} \dot{m}_f \cdot C_{p_f} \cdot T_{in}(t) \cdot dt - \int_{t_i}^{t_f} \dot{m}_f \cdot C_{p_f} \cdot T_{out}(t) \cdot dt - \int_{t_i}^{t_f} P_{loss,transient\ state}(t) \cdot dt \quad (3)$$

## eLLO receiver linear heat loss correlation

- The calculation method for transient flow regimes is validated using a 1D single-phase thermal-hydraulic model developed on MatLab,
- Thermal losses are evaluated experimentally using the methods presented, and compared with the thermal losses of the Nova-1, LF-11 and Heliotérnica modules developed by Frenell, Industrial Solar and the LEPTEN laboratory respectively.
- The heat loss correlation of the eLLO receiver is expressed as linear thermal losses [W/m] as a function of the inlet/outlet fluid temperature average and the ambient temperature :

$$P_{loss-eLLO} = 6.9 \times 10^{-3} (T_{in/out} - T_{amb})^2 + 1.6420 (T_{in/out} - T_{amb}) \quad (4)$$



## Conclusion and acknowledgements

Technical constraints linked to the industrial scale of the system led to the definition and validation of a new calculation method to evaluate the heat loss of the eLLO solar receiver for a transient flow regime. Finally, a linear heat loss correlation is constructed experimentally using appropriate calculation methods as a function of the flow regime in the solar lines. In conclusion, the heat loss law for the eLLO receiver shows results within the range of heat loss correlations described by manufacturers of other modules.

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