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## ENERGY EFFICIENCY:

$$\eta_{en} = \frac{V_{OC} \cdot I_{SC} \cdot FF}{A \cdot G}$$

## EXERGY EFFICIENCY:

$$\eta_{ex} = \frac{V_{OC} \cdot I_{SC} \cdot FF + Q \left(1 - \frac{T_a}{T_m}\right)}{AG \left[1 - \frac{4}{3} \left(\frac{T_a}{T_s}\right) + \frac{1}{3} \left(\frac{T_a}{T_s}\right)^4\right]}$$

Exergy analysis includes a consideration of energy quality or capability. This analysis quantifies both the usable energy (**availability**) and unusable energy (**irreversibility**), which allows a more effective and efficient evaluation of the use of energy potential to know the efficiency in energy utilization.

In Figure 1, one can see the exergy input and the exergy output, divided in electric exergy and thermal exergy. It can also be seen that the exergy loss is very high, constituting around 85% of the exergy input, due to irreversibilities in the process.

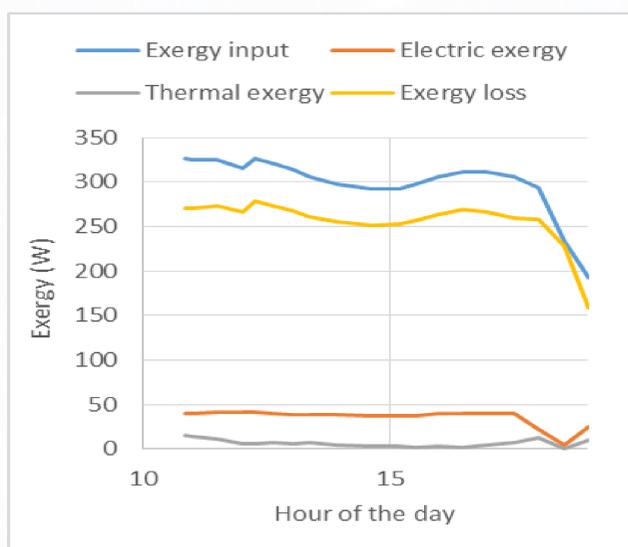


Figure 1. Exergy balance of the module on a sunny day.

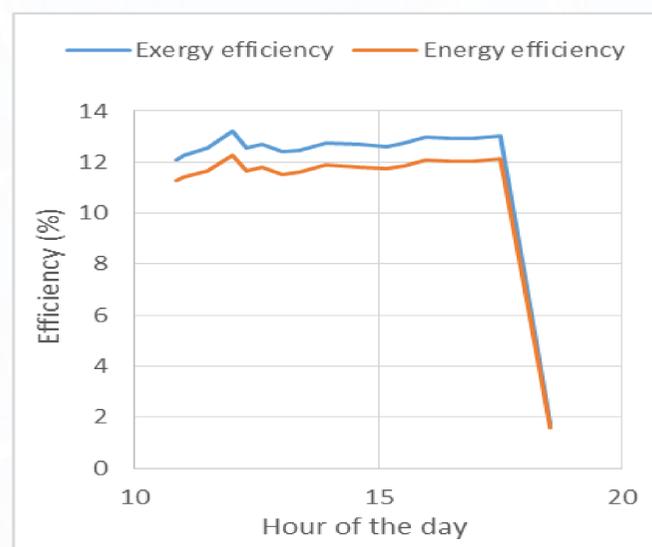


Figure 2. Exergy and energy efficiency of the module on a sunny day.

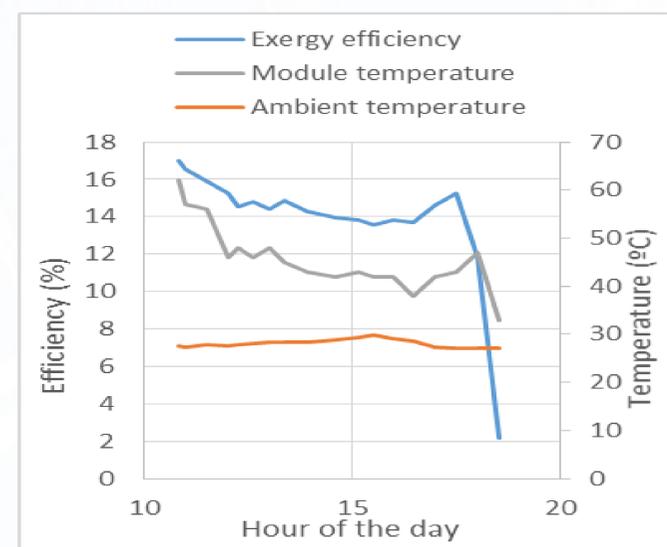


Figure 3. Exergy efficiency, module temperature and ambient temperature of the module on a sunny day.

In Figure 3, it can be seen that the efficiency is proportional to the module temperature. Common sense tells us that increasing the module temperature should not be beneficial for exergy efficiency, as thermal losses increase with temperature, and thus irreversibilities. Therefore, we came to the conclusion that thermal exergy should not be considered as an exergy output, but rather an exergy loss.

## CORRECTED EXERGY EFFICIENCY:

$$\eta_{ex} = \frac{V_{OC} \cdot I_{SC} \cdot FF}{AG \left[1 - \frac{4}{3} \left(\frac{T_a}{T_s}\right) + \frac{1}{3} \left(\frac{T_a}{T_s}\right)^4\right]}$$

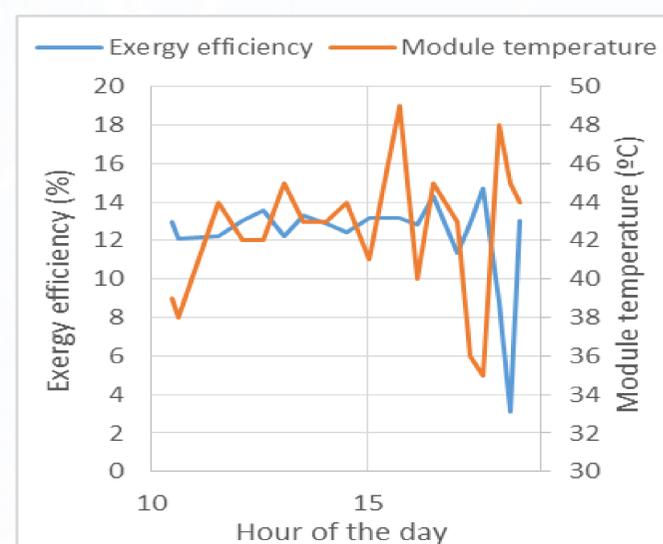


Figure 4. Corrected exergy efficiency and module temperature on a cloudy day.

## ACKNOWLEDGEMENT

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