Analysis of a hybrid photovoltaic-thermoelectric system

Dimitrios Kossyvakis[1,2 *], Evangelos Hristoforou[1], George Kavvouras[3], Spyridon Koutroumpas[1,4]

[1] Sensors Lab, National TU of Athens, Athens, Greece
[2] Cablel Hellenic Cables S.A., Athens, Greece
[3] VINCI ENERGIES/Omexom Hellas S.A., Athens, Greece
[4] Tenagis S.A., Athens, Greece
*dkossyvakis@hellenic-cables.com

ABSTRACT

Renewable energy technologies stand today as a feasible and sustainable solution for achieving a fossil fuel free power generation model, promising sufficient energy production and minimizing the costs in mineral wealth. Amongst them, photovoltaic cells (PV) have seen significant performance improvement during the last years.

However, photovoltaics still face certain drawbacks by the thermal fatigue developed on the photovoltaic panels, which leads to deterioration of electrical performance. Therefore, an important issue refers to methods for maintaining the performance of PVs by decreasing the operating temperature of the cells.

In this work, the implementation of thermoelectric generators (TEGs) to harvest the thermal energy of PVs is demonstrated, suggesting that they can be used for the cooling of the PVs, while contributing also to the electrical power generation scheme.

INTRODUCTION

- **Photovoltaics** are a key component in **decarbonization** policies worldwide**.**
- PV performance dependence vs. **temperature** still acts as a drawback**.**
- **Effective cooling** of the PV devices during operation becomes necessary**.**
- Thermoelectric generators **(TEGs)** can exploit existing temperature gradients for power generation purposes**.**
- They do not produce **noise** or **vibrations** and require only **minimal maintenance.**
- **TEGs** have emerged as a promising alternative for **hybridization** with PV devices, acting as a **cooling mechanism.**
- **Efficiency improvement** is obtained due to the cooling of the cells**.**
- **Additional electrical power** is produced also by the **TEG** subsystem.

KEY COMPONENTS OF THE EXPERIMENTAL APPARATUS

Photovoltaic Subsystem

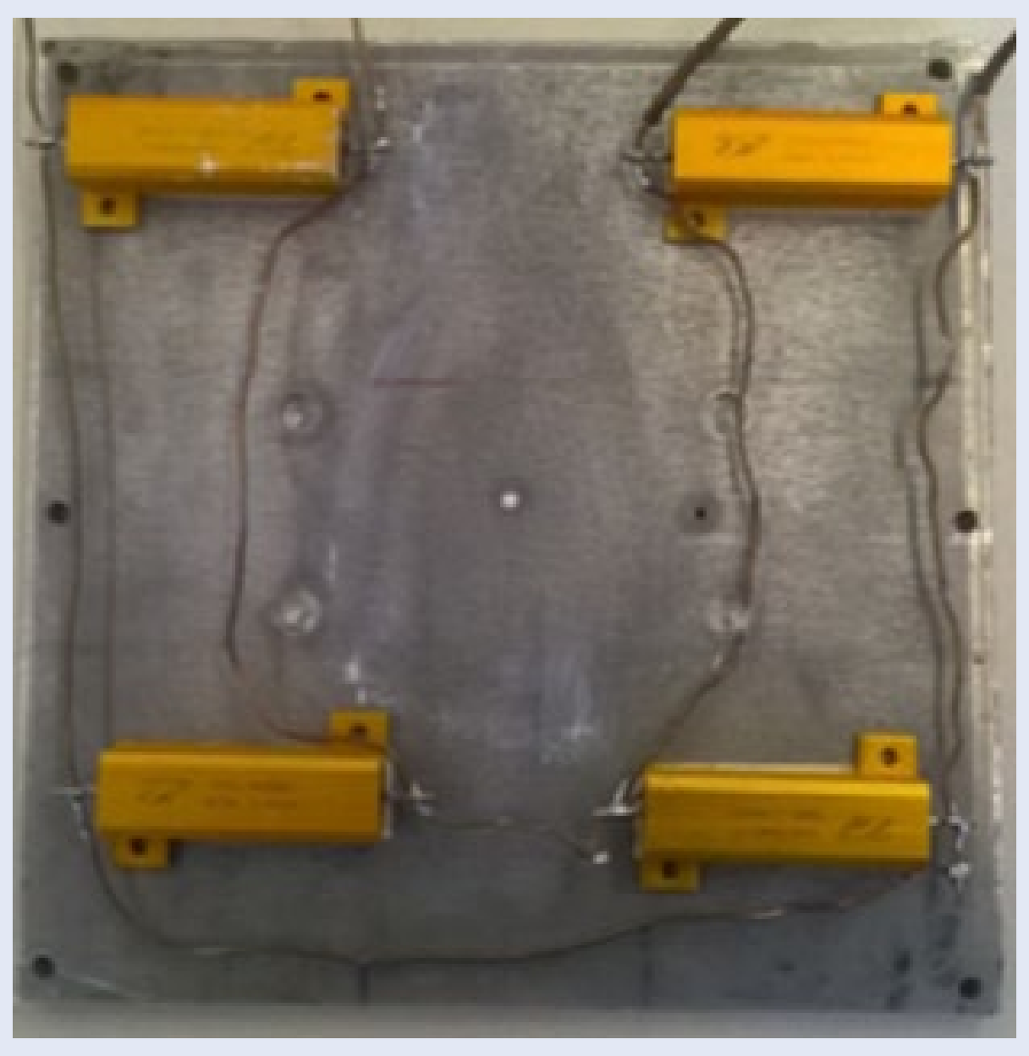
Polycrystalline PV cell

Thermoelectric Subsystem

Bi_2Te_3 Thermoelectric Generator

Bi_2Te_3 *thermoelectric generators are widely available on a commercial basis and their operating* ***temperature range*** *(up to* ***250 °C****) provides a good match to the operating temperature of the photovoltaic subsystem.*

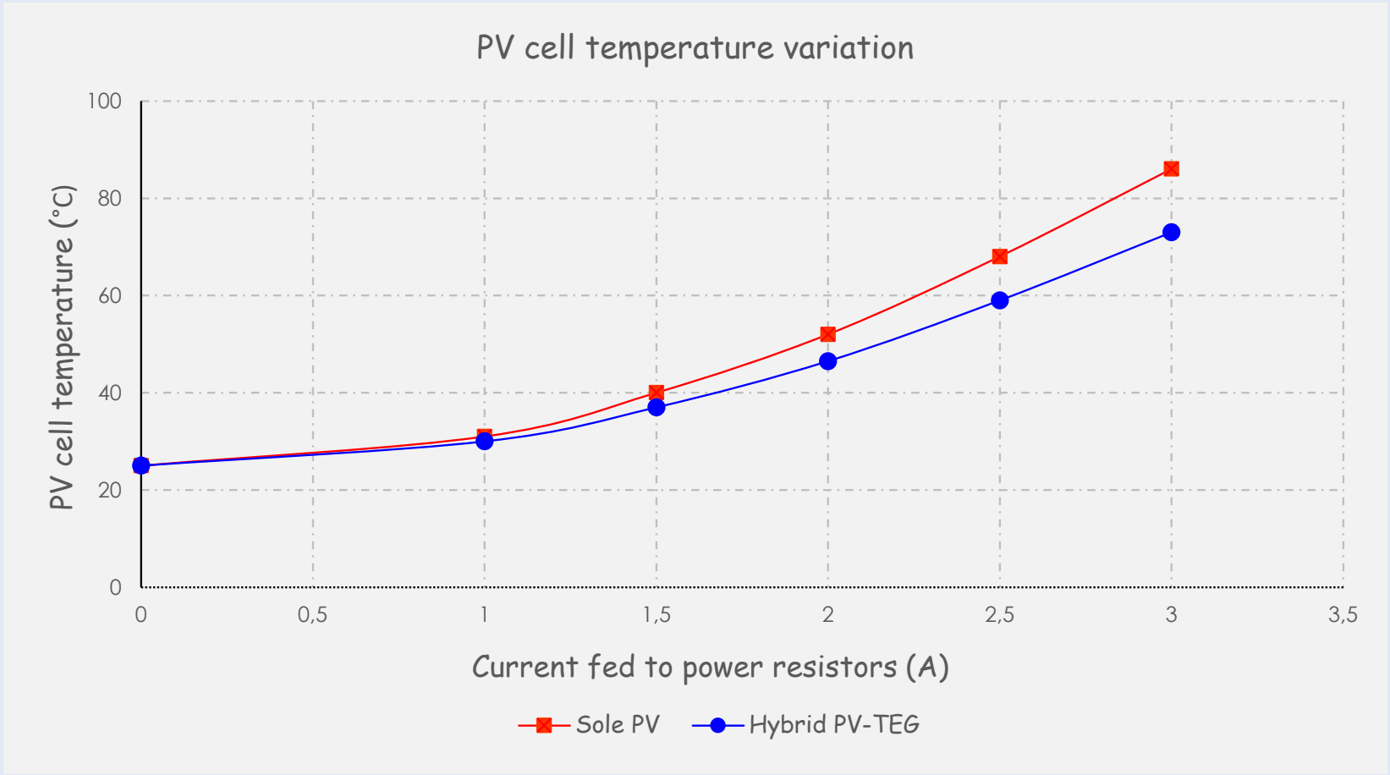
FINAL EXPERIMENTAL SETUP

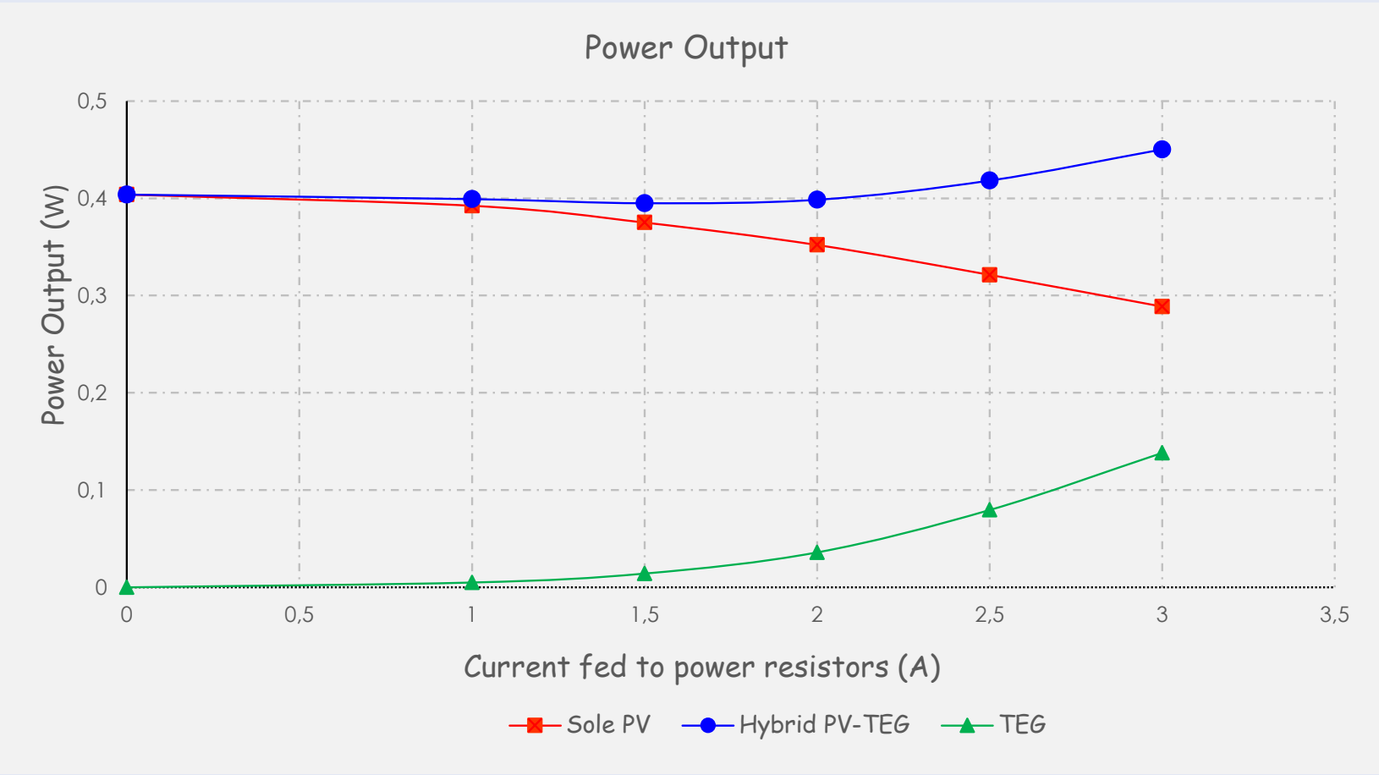


The experimental setup includes the following main components:

- A polycrystalline solar cell.
- A thermoelectric generator (thermoelement size of 1.4x1.4x1.6 mm^3).
- A water cooled heat sink attached on TEG cold side.
- Power resistors for raising the temperature of the PV cell.
- A LED lamp to provide artificial light to the PV cell.

EXPERIMENTAL RESULTS





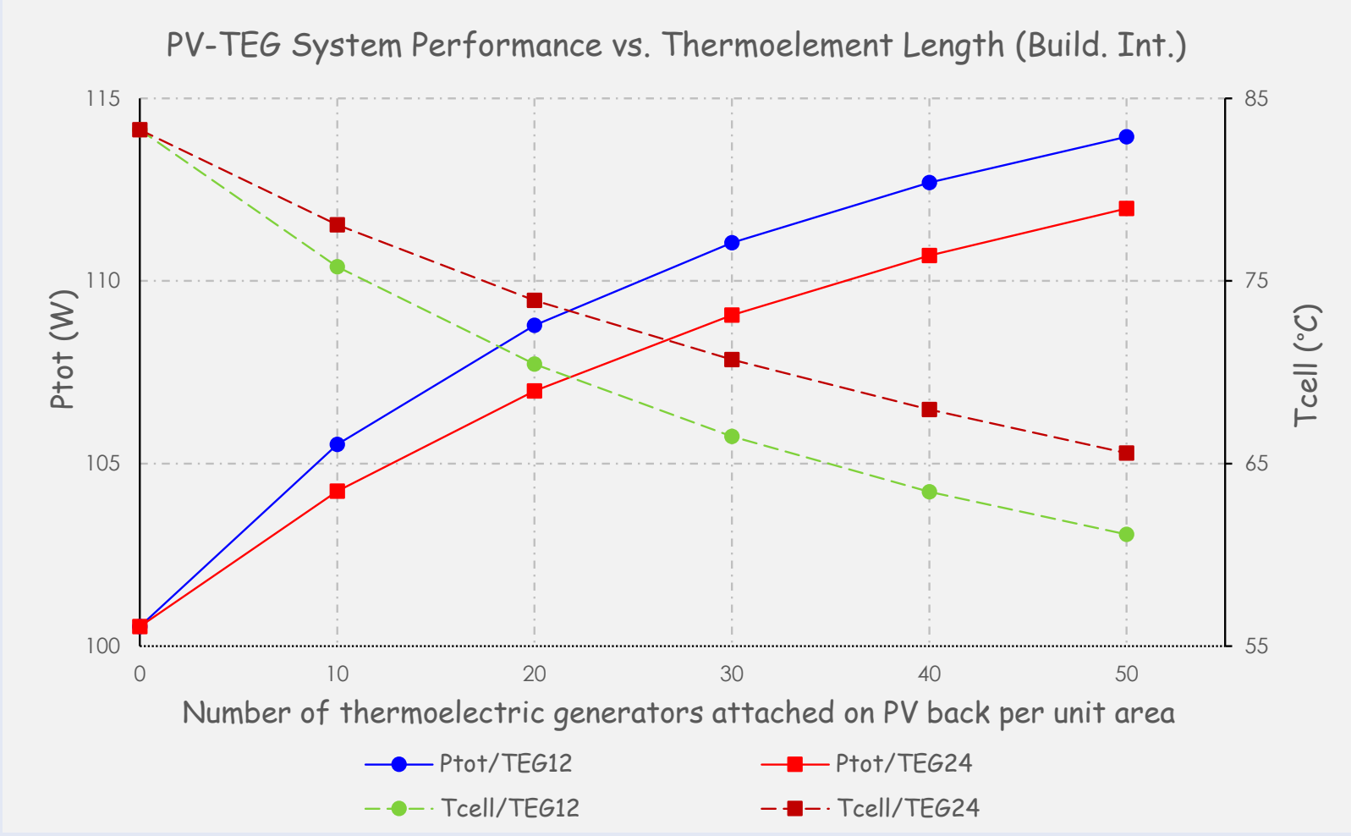
- Maximum temperature decrease of **13 °C** due to hybridization.
- The corresponding performance boost exceeds **10%** vs. room temperature performance.

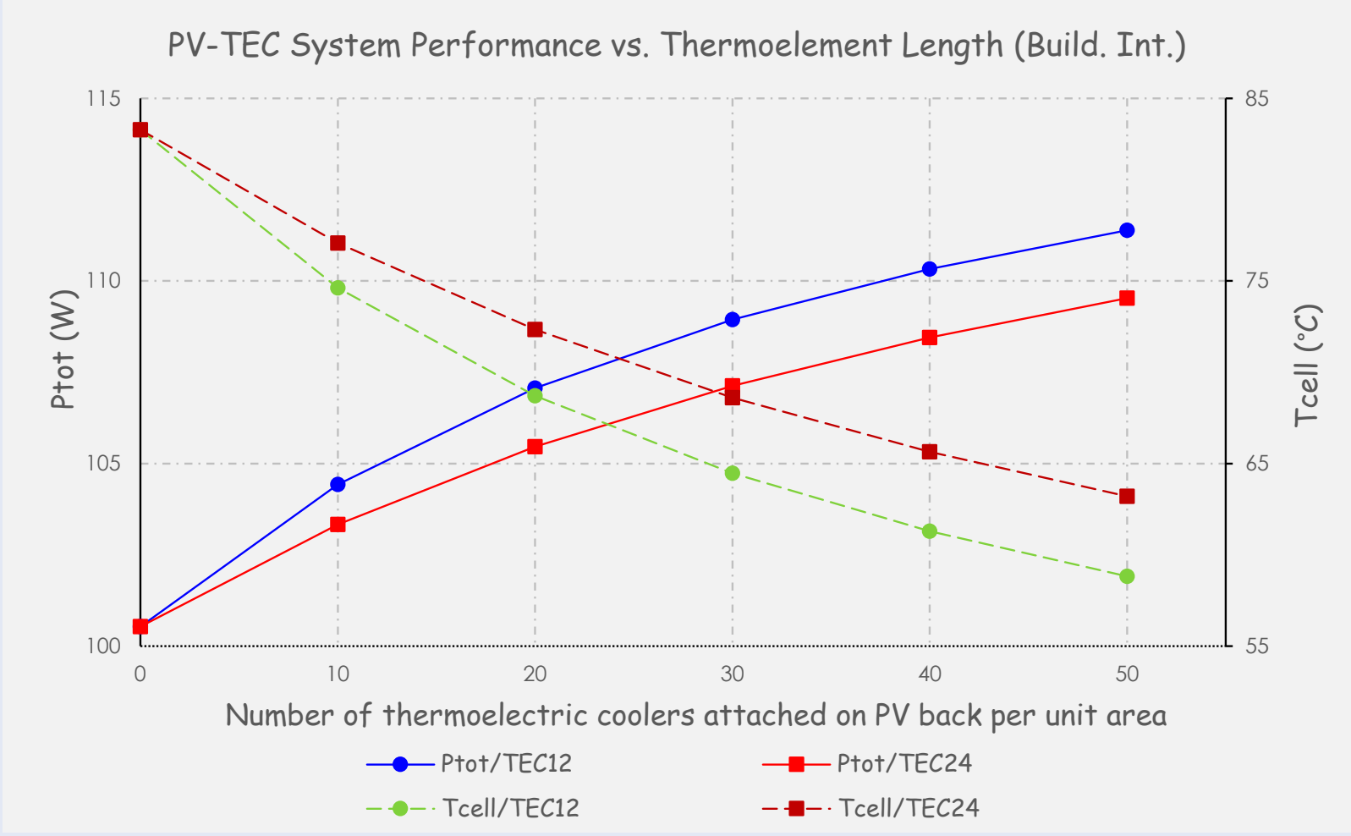
THEORETICAL INVESTIGATION

Theoretical performance evaluation conducted on the basis of existing analytical models:

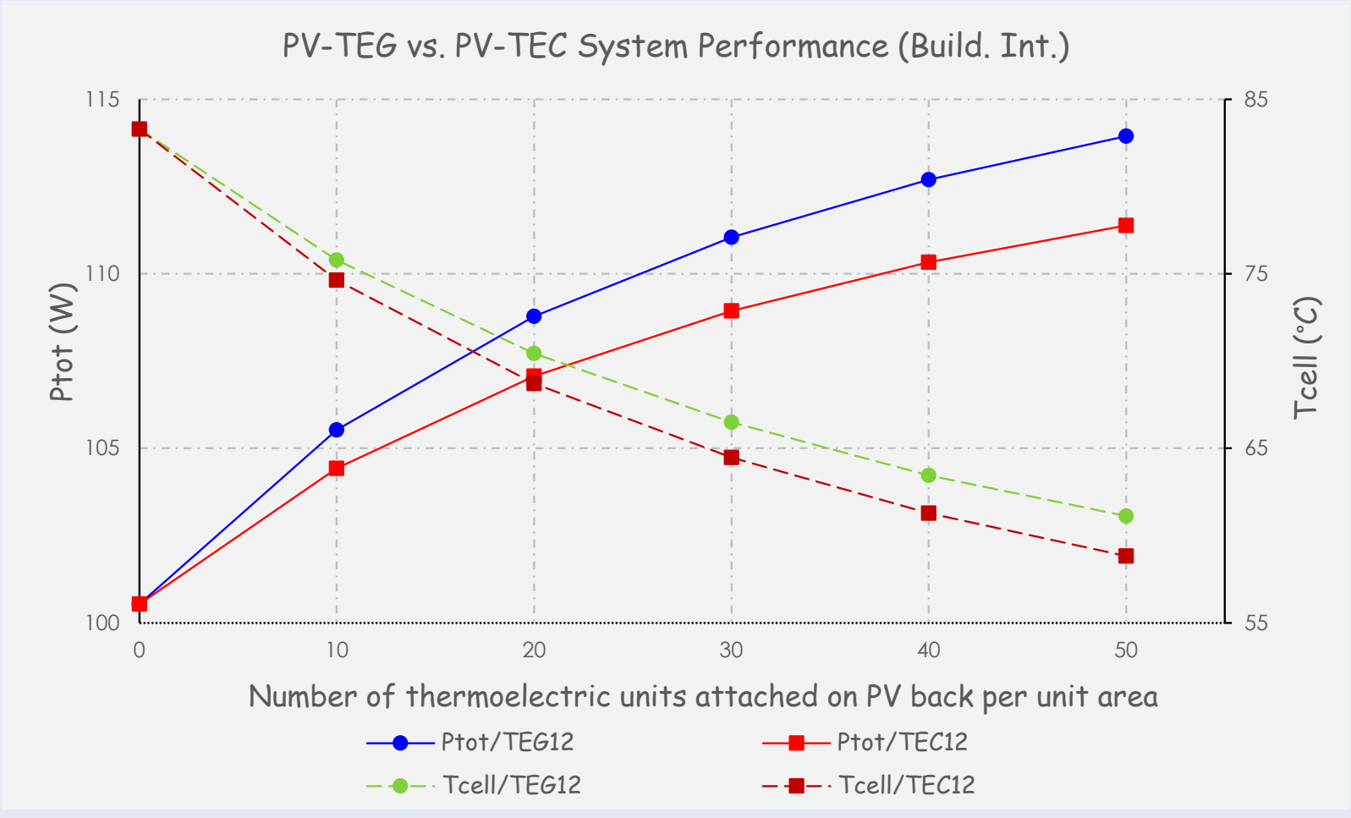
- Thermoelectric device assumed to operate both on **Seebeck** (simultaneous cooling & power generation) and **Peltier** (cooling only) mode.
- The performance effect of **thermoelement length** has been assessed.
- Different installation conditions have been examined (**building integrated** & **rooftop PV**).
- System's **optimum operating point** is identified.
- Analysis can be extended to **any type of PV installation** operating under a similar temperature range.

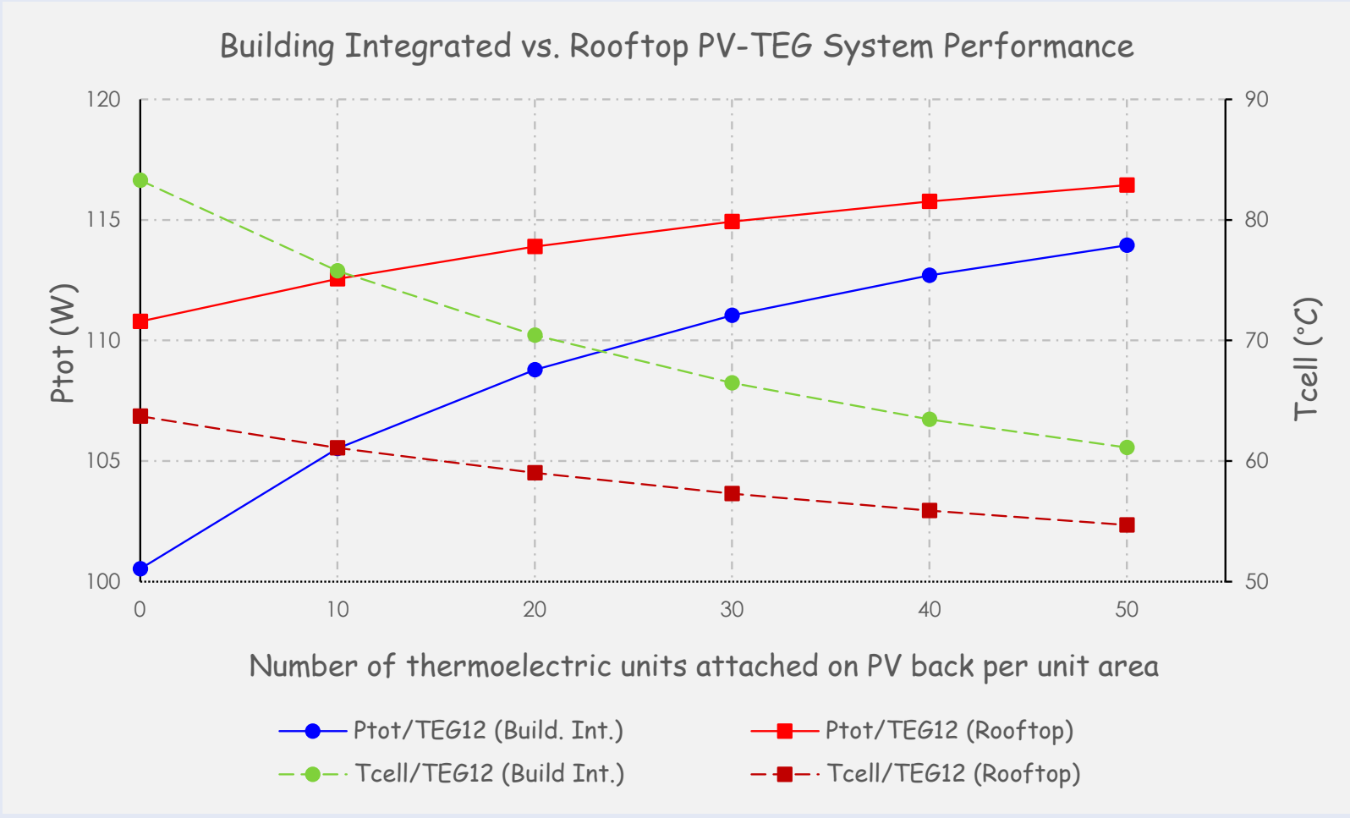
RESULTS



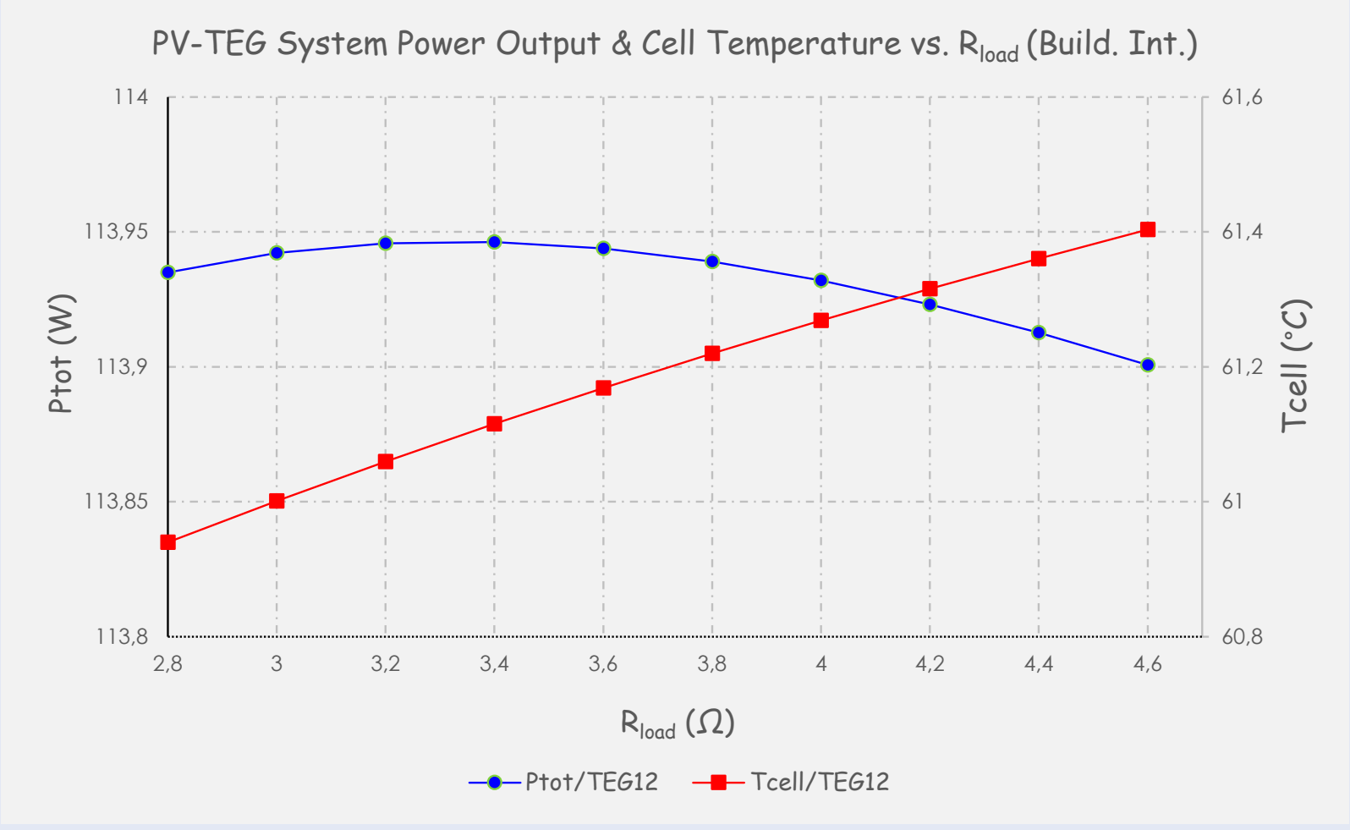


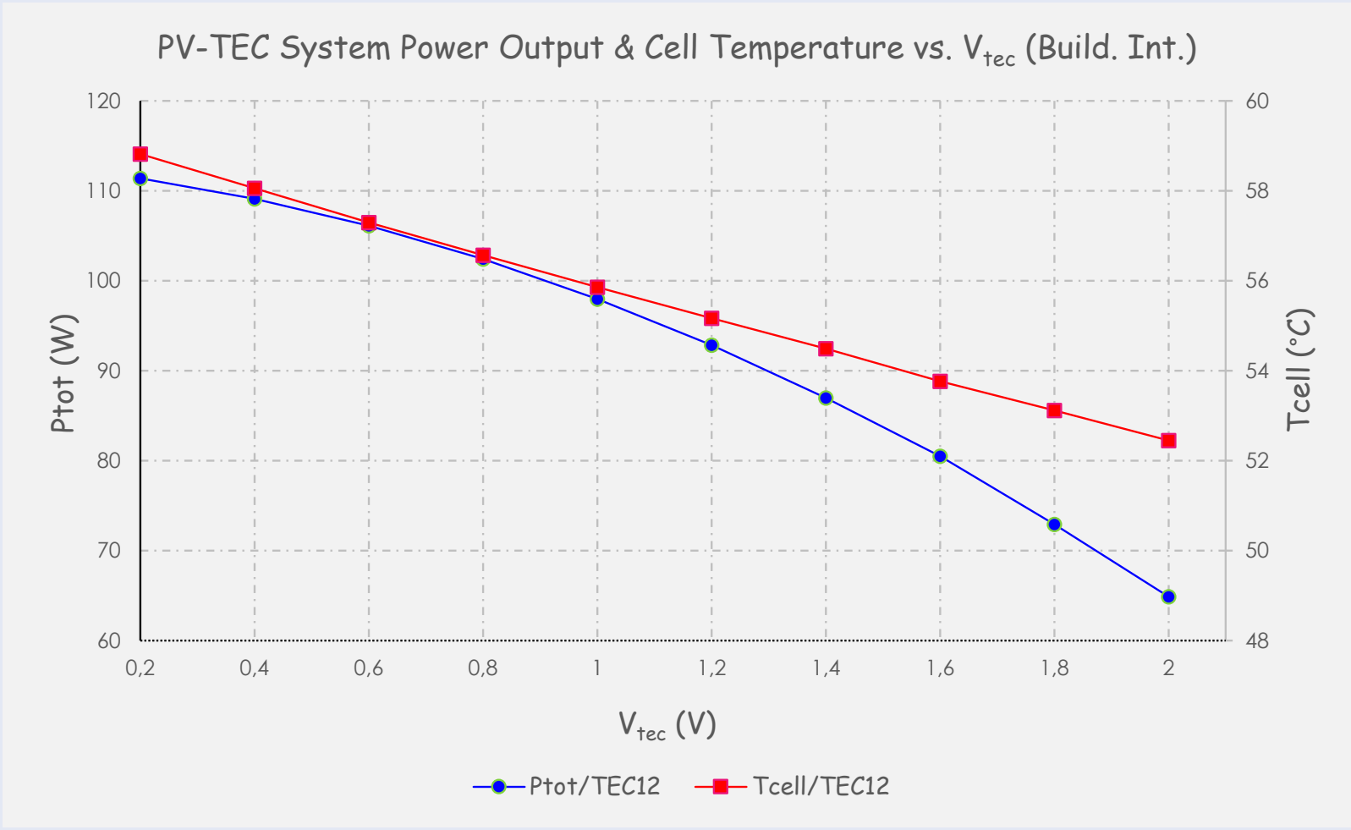
- Both operating modes (Seebeck & Peltier) provide improved performance in terms of **system power output** (boost up to **13%**) and **operating temperature** (up to **24 °C** decrease).
- The performance effect depends strongly on the **number of thermoelectric units** employed.
- Hybrid operation becomes more effective for thermoelectric devices of **lower thermoelement length**.





- **Seebeck** mode provides **optimum** performance in terms of **system power output**.
- **Peltier** mode results in the **lowest operating temperature** for the PV cell.
- The higher the **initial operating temperature of the cell** the more pronounced is the performance improvement.





- **Maximum power point** does not coincide to the operating condition providing the lower temperature for the PV cell, which is true for both thermoelectric modes (**Seebeck** & **Peltier**).

CONCLUSIONS

- Experimental and theoretical investigation of **PV-TEG** and **PV-TEC** hybrids.
- Both hybrid systems examined **improve** overall performance efficiency.
- **Seebeck** mode favors system's **power output**.
- **Peltier** mode leads to the lower **PV cell operating temperature**.
- **Number of TEG (TEC) units** & **thermoelement length** are critical design parameters.