Design and optimization of printed thermoelectric generators for integration into plate heat exchangers in district heating applications

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1. Introduction

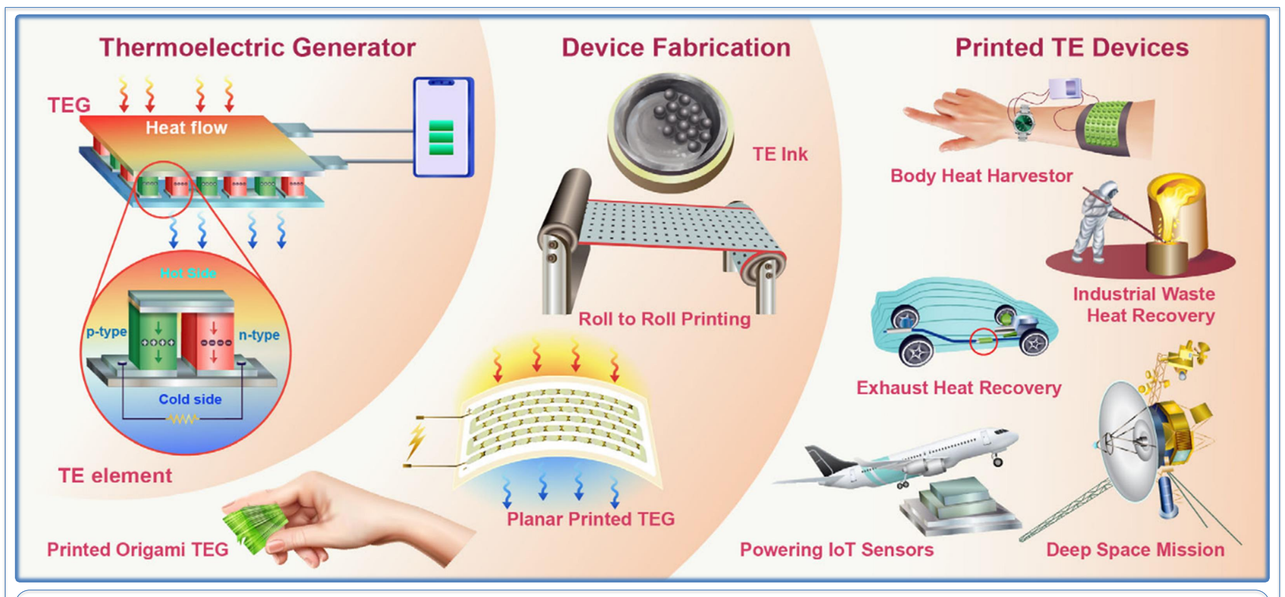
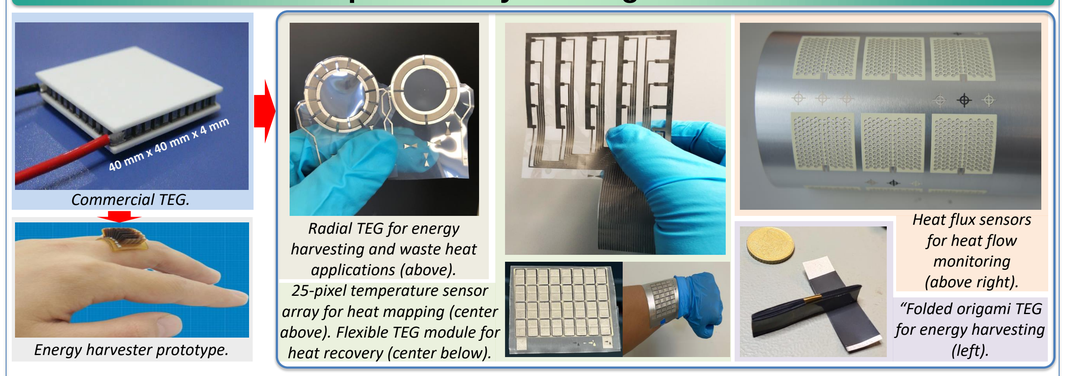


Figure 1 | Schematics of the TEG working, materials processing, printed device fabrication, and the applications of the thermoelectric devices [1].

Thermoelectric generators (TEGs) could be viable a solution for waste heat recovery for combined heat and power (CHP) systems. Due to large variations in heat source and heat sink geometries, heat transfer coefficients, and temperatures, shape-conformable TEGs can be manufactured using low-cost and scalable manufacturing approaches; screen printing or 3D printing [2].

3. Motivation

✓ Shape varstility in design & fabrication



Commercial TEG.

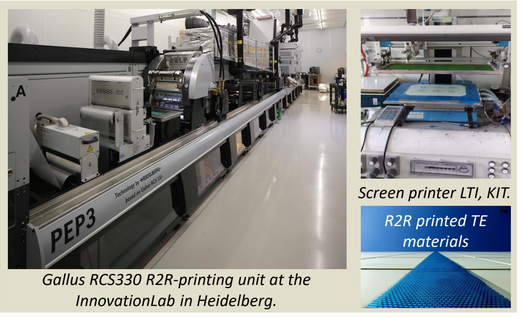
Energy harvester prototype.

Radial TEG for energy harvesting and waste heat applications (above). 25-pixel temperature sensor array for heat mapping (center above). Flexible TEG module for heat recovery (center below).

Heat flux sensors for heat flow monitoring (above right).

"Folded origami TEG for energy harvesting (left).

✓ Scalable production



Gallus RCS330 R2R-printing unit at the InnovationLab in Heidelberg.

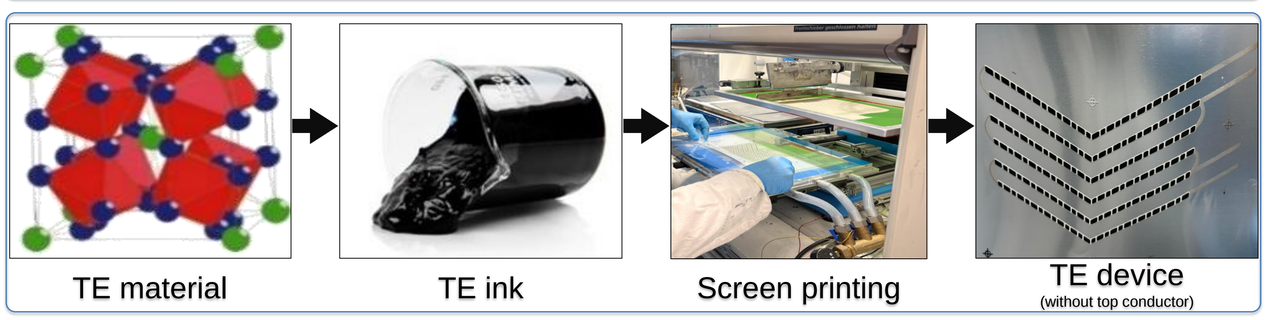
Screen printer LTI, KIT.

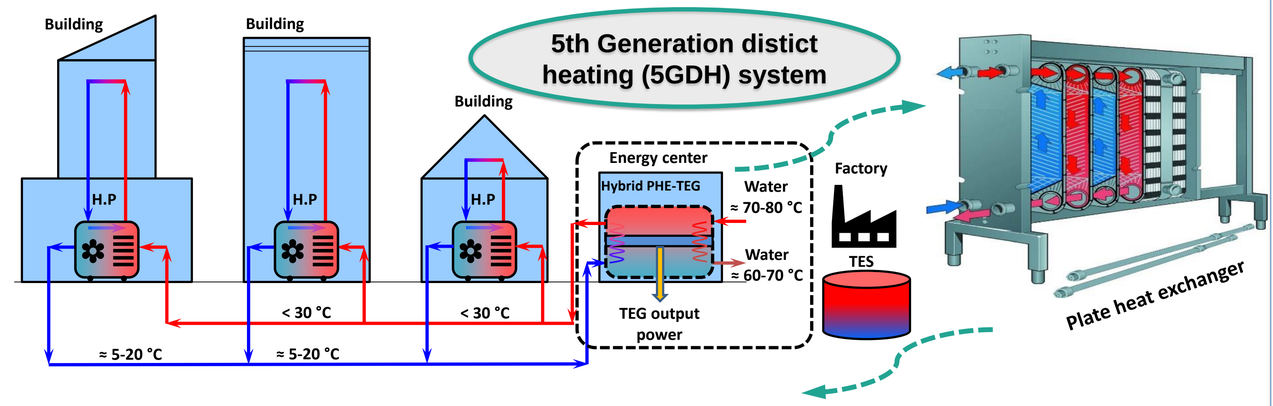
✓ Lower cost

➢Printed TEGs manufactured by large-scale screen printing, ink-jet printing, or 3D printing offer fast and simple manufacturing processes lowering the costs and allowing for a potential competitiveness in the market [2].

2. Approach & Methodology

✓ Printed TEG manufacturing approach & application environment

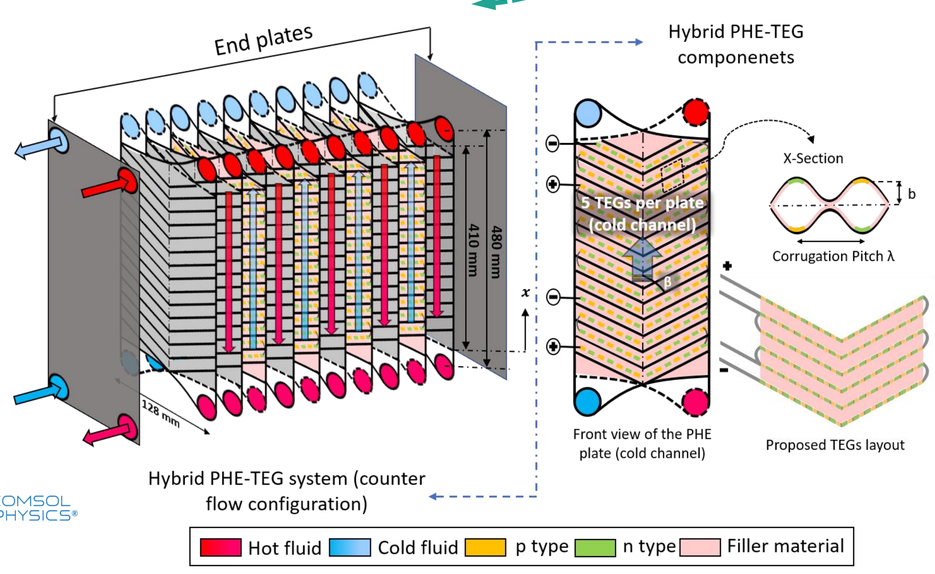




Cost of electricity

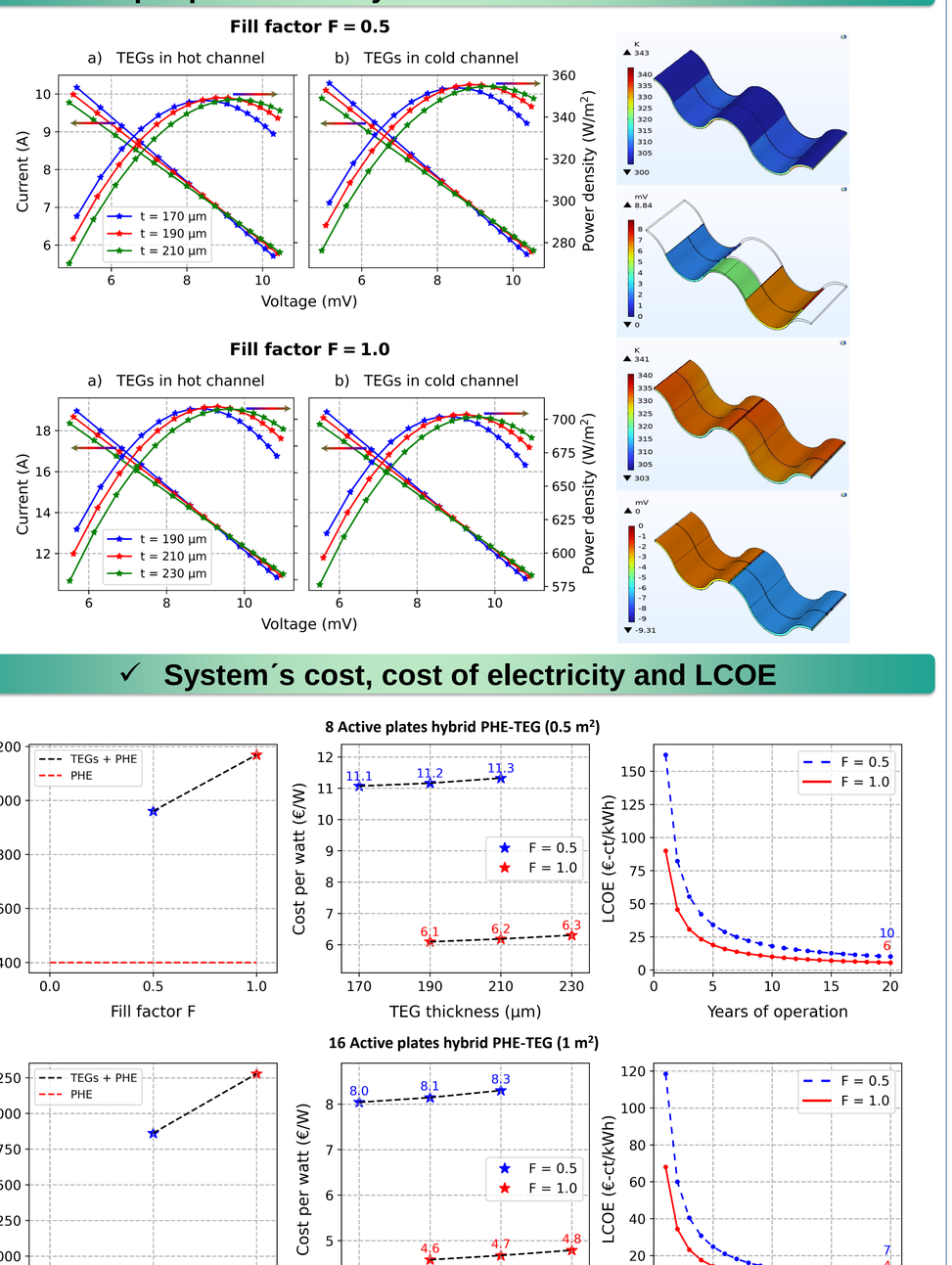
- Component costs (€).
- Cost of electricity per unit watt (€/W).
- Levelized cost of electricity (LCOE) per unit kilo watt hour (€/kwh).

$$LCOE = \frac{I_t + \sum_{t=1}^{n} \frac{O_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$



4. Results

✓ TEG output power density at different fill factor and thicknesses



✓ System´s cost, cost of electricity and LCOE

5. Conclusion

- Utilizing low-grade heat for 5th generation district heating and electricity production.
- Design optimization of printed TEGs for plate heat exchanger in 5GDH.
- Techno-economic performance analysis of the proposed system.

6. References

[1] Sarbajna, A., Rösch, A. G., Franke, L., Lemmer, U. & Mallick, M. M. Inorganic- Based Printed Thermoelectric Materials and Devices. Adv. Eng. Mater. 25, 2200980 (2023).

[2] Rösch, A. G., Franke, L., Mallick, M. M. & Lemmer, U. Optimizing printed thermoelectric generators with geometry and processibility limitations. Energy Convers. Manag. 279, (2023).

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