# IMPERIAL

# Multifunctional solar processor

## Integrated energy generation and plastics processing with full-spectrum solar harnessing

**Francesco Polito*, Professor Christos N. Markides**

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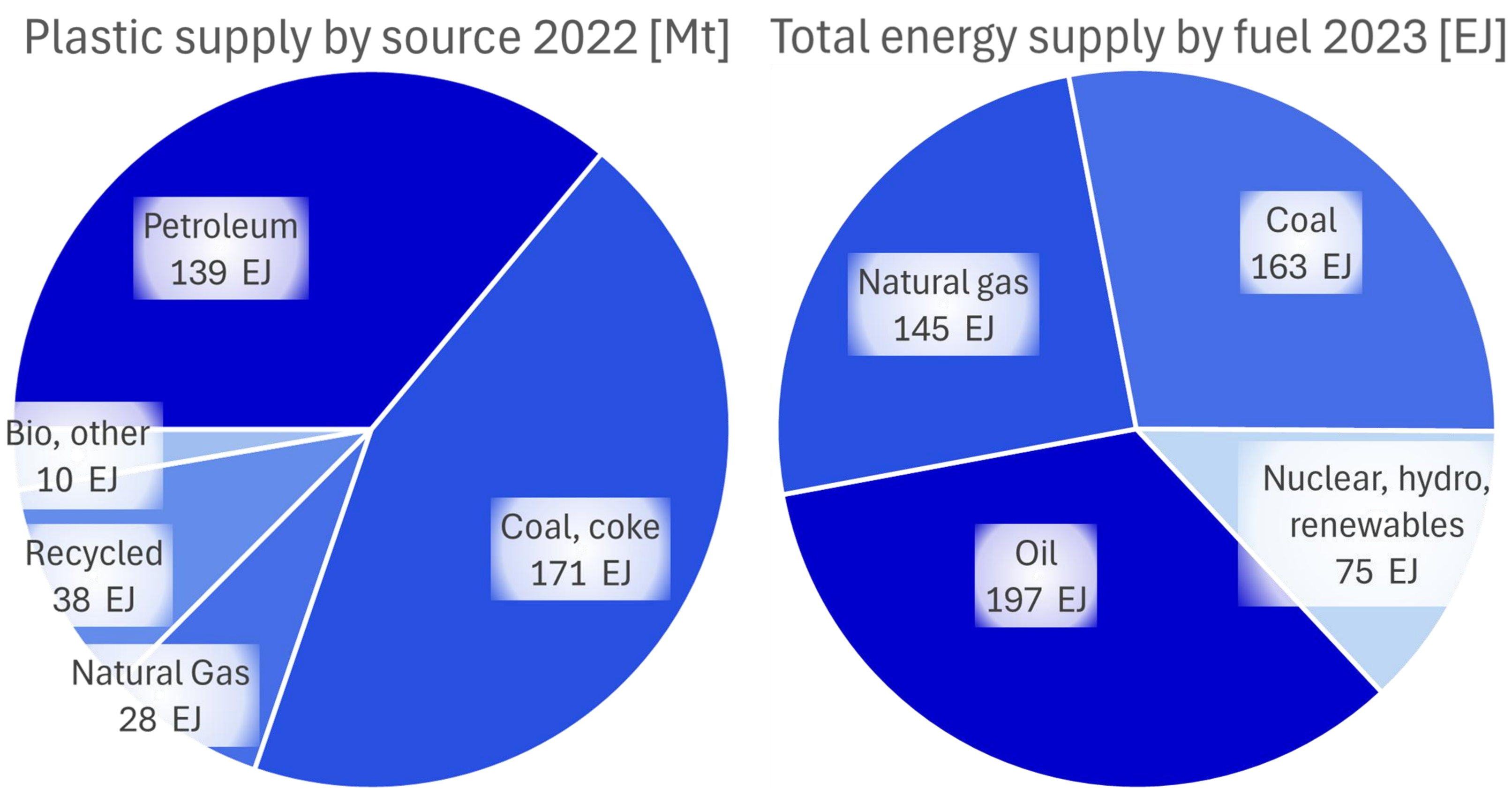
Plastic pollution has permeated the very fabric of life itself with global production reaching > 450 Mton/yr.

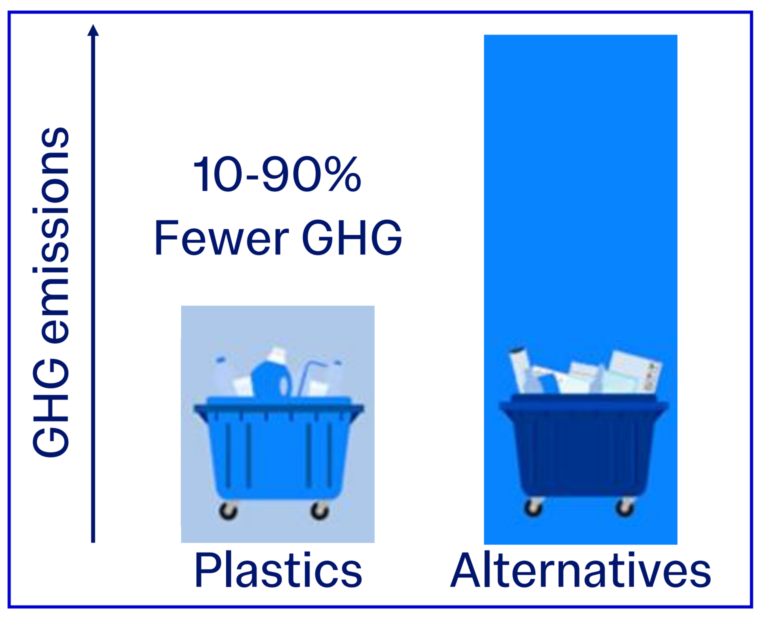
Circularity concerns have increased the share of recycled plastic; however, this is far from keeping pace with the rapid production expansion leading to growth in virgin plastic from fossil fuels [1].




Global plastic supply by source 2022 [3] and total energy supply by fuel 2023 [4]

## Fully replacing plastics is not the solution

The use of alternative materials like glass, wood, paper, or metal is both unfeasible and environmentally counterproductive as their life-cycle impact would impose greater environmental burdens. [2]



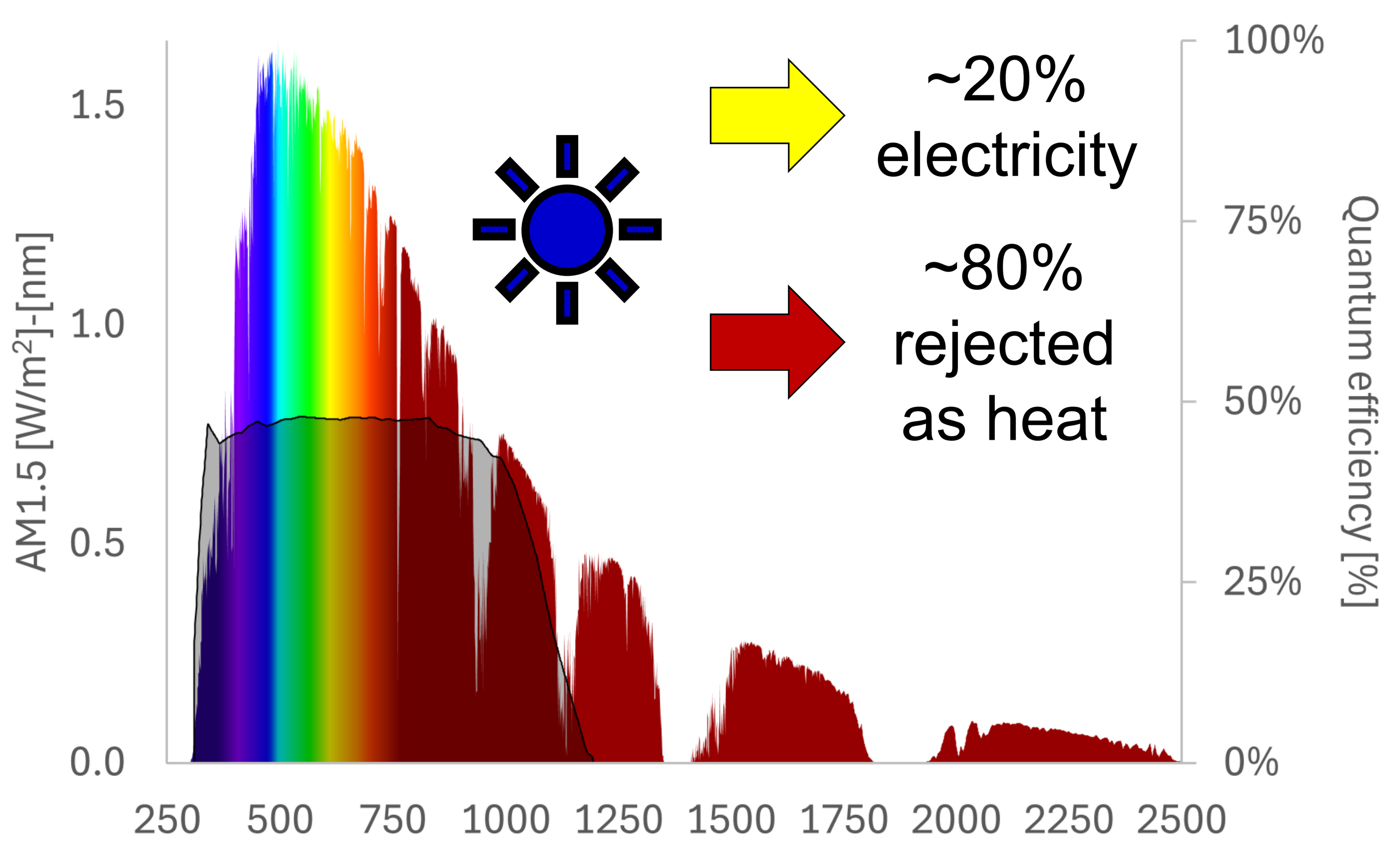

GHG emission associated with full plastic phase out [2]

Alongside plastics, energy constitutes a central pillar of today's economies, which continues to be dominated by fossil fuels.

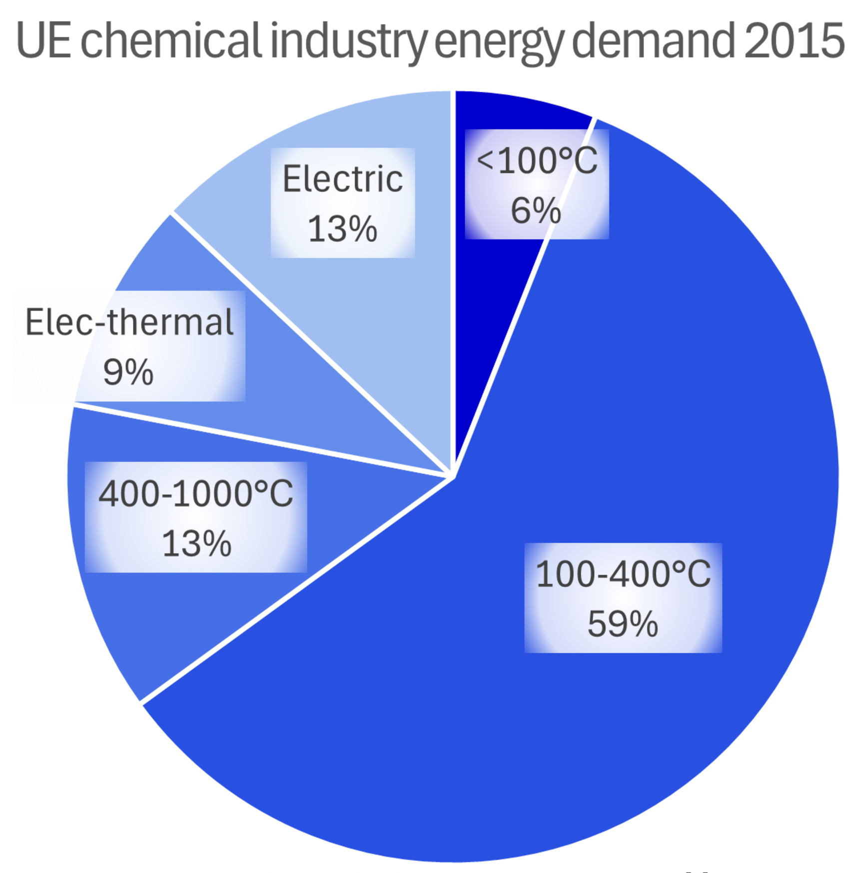
## 88% of plastic [3] and 87% of energy [4] production are fossil-based

Electrification creates a strategic upstream decarbonisation opportunity that must be seized. Solar PV is the fastest-growing renewable source, with global capacity rising almost 35-fold between 2010 and 2023 [5].

However, typical PV modules are ~20% efficient at generating electricity, with most of the incident energy lost as heat (>70%) [6]. Despite harming PV performance, heat is a valuable resource; over 65% of EU chemical-industry energy demand is for <400 °C heat [7]. Most chemical processes for value-added products still require carbon-intense external energy inputs (e.g., grid electricity, heat from onsite heaters) and use traditional compartmentalised process design principles.




AM1.5 solar spectrum [8] and quantum efficiency of a commercial mono-crystalline silicon PV module [9]




European union chemical industry energy demand 2015 [7]

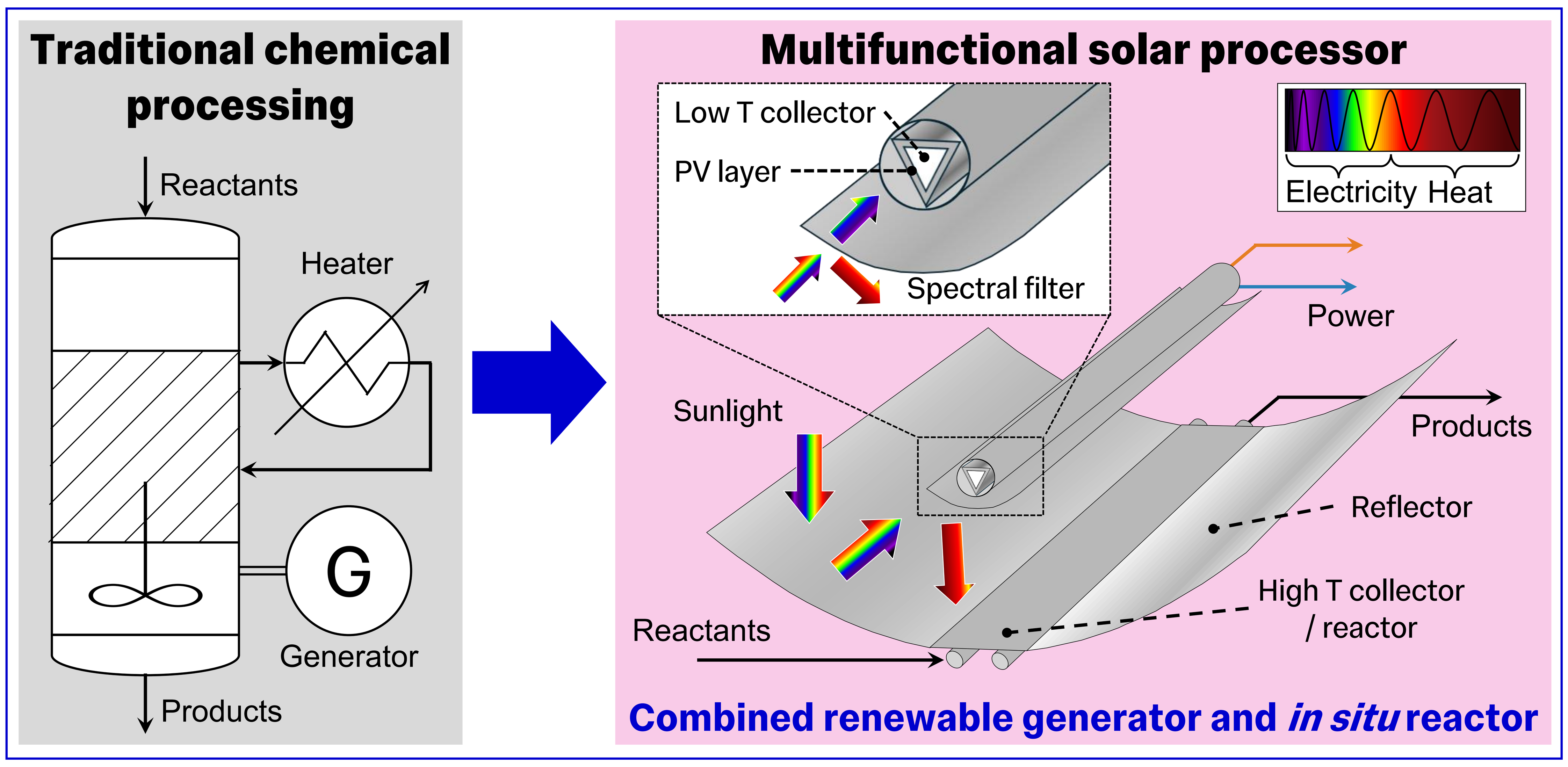
The vision is to shift from separated energy supply and processing to an integrated multifunctional solar processor (MSP): heat and power demands are met by the reactor while exploiting synergies.

- Enhanced PV generation (cell cooling)
- Waste heat recovery (full spectrum use)
- Fewer components required
- Lower transmission losses

We propose to explore the viability of an MSP for plastics recycling to improve recycling economics and address currently unmanaged plastic waste.

Our objective is not to develop new, but to integrate selected, state-of-the-art reactions into a unified, self-sufficient device. The initial target for integration is alkaline PET hydrolysis which is preferrable for:

- Lower temperature requirements
- Known depolymerisation method
- Vast amount of PET waste




Comparison of traditional externally powered chemical processing with the MSP approach applied to a spectral splitting design from [10], which integrates heat and power generation for self-sufficient operation

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|---|---|---|---|
| PET Glycolysis | ▪220°C, 45 min, uncatalyzed<br>▪190°C, 210 min, TBT catalyst<br>F. Pardal and G. Tersac *Polym Degrad Stab*, 2007, doi:10.1016/j.polymdegradstab.2007.01.008 | PET Acid Hydrolysis | ▪220°C, 3h, 95% TPA<br>▪No separation<br>FW. Yang et. al., *Waste Management*, 2021, 10.1016/j.wasman.2021.09.009 |
| PET Methanolysis | ▪200°C, >65% yield, AIP catalyst<br>▪200°C, >85% yield, AIP+Tol<br>H. Kurokawa et al., *Polym Degrad Stab*, 2003, 10.1016/S0141-3910(02)00370-1<br>S. Muangmeesri et al., *ACS Sustain Chem Eng*, 2024, 10.1021/acssuschemeng.3c07435 | PET Basic Hydrolysis | ▪100°C, 4h, 93.5% TPA<br>▪Distillation and neutralisation<br>HJ. Payne and M. D. Jones, *ChemSusChem*, 2021, 10.1002/cssc.202100400<br>A. Barredo et al., *J Environ Chem Eng*, 2023, 10.1016/j.jece.2023.109823 |
| PET Ammonolysis | ▪130°C, 6h, n-hexylamine, 85%<br>▪100°C, 3h, 3-amino-1propanol<br>S. Hiruba et al., *Catalysts*, 2025, 10.3390/catal15020129 | PET Neutral Hydrolysis | ▪270°C, 2h, 85% TPA<br>▪Saturated liquid<br>P. Pereira et al., *ACS Sustain Chem Eng*, 2023, 10.1021/acssuschemeng.3c00946 |
| Nylon 66 Ammonolysis | ▪200°C, 3 bar, 72h, $Nb_2O_5$, 99%<br>▪200°C, 3 bar, 5h, $Nb_2O_5$, 25%<br>R. Coeck and D. E. De Vos, *Chem. Commun*, 2024, 10.1039/D3CC05462D | PE Solvolysis | ▪200°C, 15h, n-pentane<br>▪$73_{wt}$% PE to linear alkane ($C_5$)<br>L. D. Ellis et al., *ACS Sustain Chem Eng*, 2021, 10.1021/acssuschemeng.0c07612 |

[1] R. Geyer, J. R. Jambeck, and K. L. Law, "Production, use, and fate of all plastics ever made," Sci Adv, vol. 3, no. 7, p. e1700782, Nov. 2025, doi: 10.1126/sciadv.1700782
[2] F. Meng, M. Brandão, and J. M. Cullen, "Replacing Plastics with Alternatives Is Worse for Greenhouse Gas Emissions in Most Cases," Environ Sci Technol, vol. 58, no. 6, pp. 2716–2727, Feb. 2024, doi: 10.1021/acs.est.3c05191
[3] K. Houssini, J. Li, and Q. Tan, "Complexities of the global plastics supply chain revealed in a trade-linked material flow analysis," *Commun. Earth Environ.*, vol. 6, no. 1, p. 257, 2025, doi: 10.1038/s43247-025-02169-5.
[4] Energy Institute, KPMG, and Kearney, "Statistical Review of World Energy," London, 2025
[5] International Renewable Energy Agency (IRENA), "Renewable power generation costs in 2023," Abu Dhabi, 2024.
[6] V.-S. Hudișteanu, N.-C. Chereches, F.-E. Țurcanu, I. Hudișteanu, and C. Romila, "Impact of Temperature on the Efficiency of Monocrystalline and Polycrystalline Photovoltaic Panels: A Comprehensive Experimental Analysis for Sustainable Energy Solutions," *Sustainability*, vol. 16, no. 23, 2024, doi: 10.3390/su162310566.
[7] S. Madeddu *et al.*, "The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat)," *Environmental Research Letters*, vol. 15, no. 12, Dec. 2020, doi: 10.1088/1748-9326/abbd02.
[8] NREL, "Reference Air Mass 1.5 Spectra", visited 29 April 2026 available from: https://www.nlr.gov/grid/solar-resource/spectra-am1.5
[9] NREL, "Spectral responses of 12 commercial silicon modules", visited 29 April 2026 available from: https://datahub.duramat.org/en/dataset/module-sr-library/resource/1004264a-d8d6-4eaf-a0de-4efff68d2fc6
[10] Pandey, C., Wu, M., Oyeniran, A. et al. "Numerical study of a parabolic-trough CPV-T collector with spectral-splitting liquid filters", *Front. Energy*, 19, 949–968 (2025). doi: 10.1007/s11708-025-1028-y