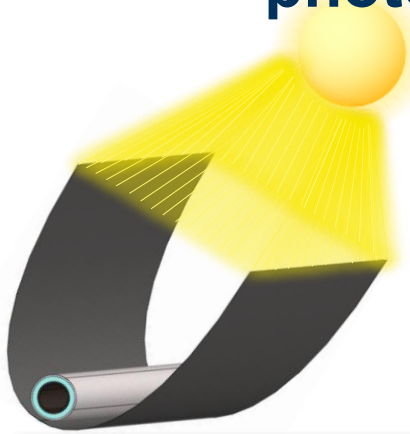
Sunlight driven green hydrogen generation: Solar concentrator assisted photocatalytic reactors for Solar-to-Hydrogen conversion



Solar driven hydrogen production

- Long term outdoor performance (> 600 h)
- Full solar spectrum utilisation (photonic + thermal)
- Scalable reactor design
- Stable, reproducible and strongly adhered catalyst coating strategy



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Introduction

- Hydrogen has a high heating value (33.33 kWh/kg) as compared to 12.33 and 12.26 kWh/kg of petrol and diesel. **[1]**
- Global hydrogen demand reached 100 Mt in 2025, with low-emissions production reached nearly 1 Mt, still under 1% of global output. **[1]**
- Annual production of low-emission hydrogen needs to reach ~47% of total demand in 2030 and ~98% (420 Mt) in 2050, with total global hydrogen demand projected to reach ~150 Mt in 2030 and ~430 Mt in 2050. **[1]**

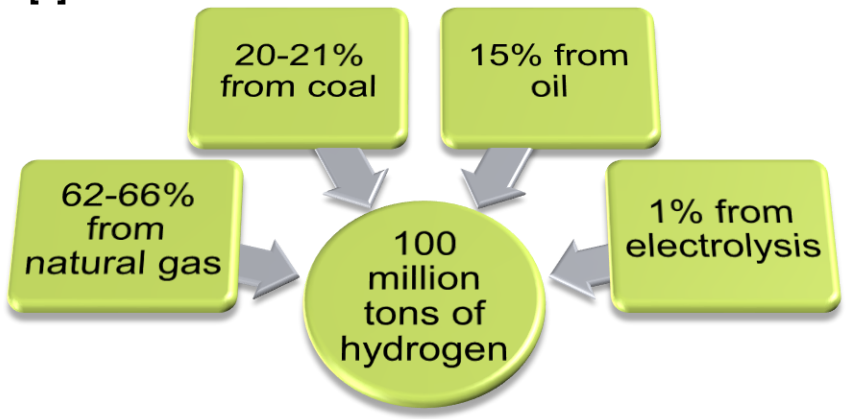


Fig. 1 Hydrogen Production with different feedstocks in 2025 **[1]**

Feedstocks	Energy Consumption (kJ/mol H_2)	Hydrogen Yield (mol H_2/mol feed)	Emission (tonnes of CO_2/ tonne of H_2)
Natural Gas	42	4	10
Oil products	50	2.7	12
Coal	60	2.3	19
Water	245	1	0

Table 1 Choice of feedstocks **[2]**

Photocatalytic water splitting

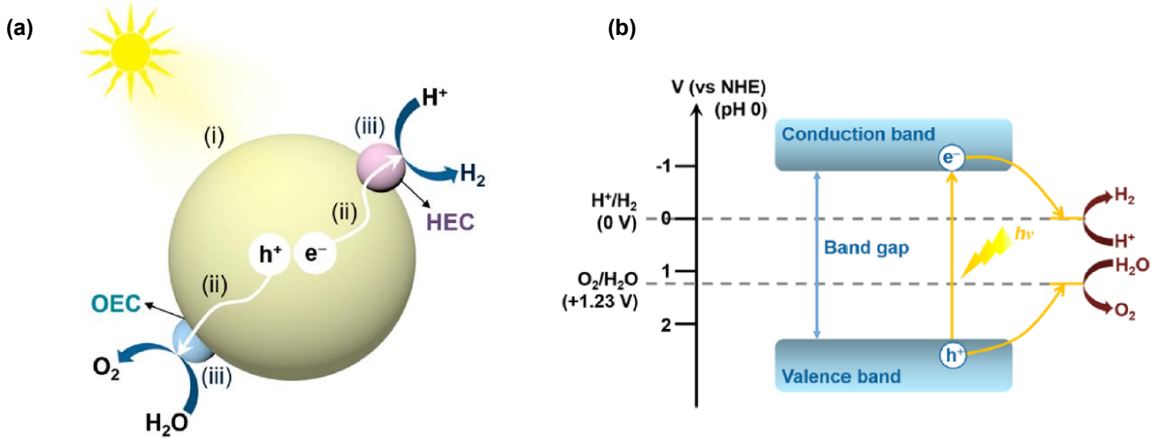


Fig. 2a. Water splitting reaction on a semiconductor photocatalyst: (i) light absorption, (ii) charge separation and transport, and (iii) redox reactions. **2b.** Energy diagram for photocatalytic water splitting

Knowledge gaps

- **Inefficient** utilisation of solar energy
- **Long-term stability & performance demonstration** at system scale not yet proven
- **System analysis** using realistic design and performance features not reported yet
- Immobilised catalyst type reactors not reported under **light concentration**
- There is a noticeable gap in **computational modelling** efforts that can integrate photocatalytic water splitting with optical and thermal simulation studies.

[1] https://www.iea.org/reports/global-hydrogen-review-2026, https://www.iea.org/reports/global-hydrogen-review-2025/executive-summary
[2] IEA, Comparison of the emissions intensity of different hydrogen production routes, 2021, IEA, Paris https://www.iea.org/data-and-statistics/charts/comparison-of-the-emissions-intensity-of-different-hydrogen-production-routes-2021, IEA. Licence: CC BY 4.0

Reactor modelling

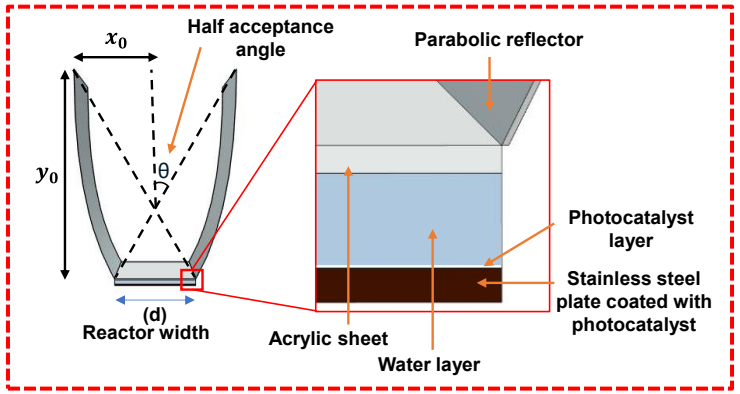


Fig. 4 CPC reflector with flat reactor modelled

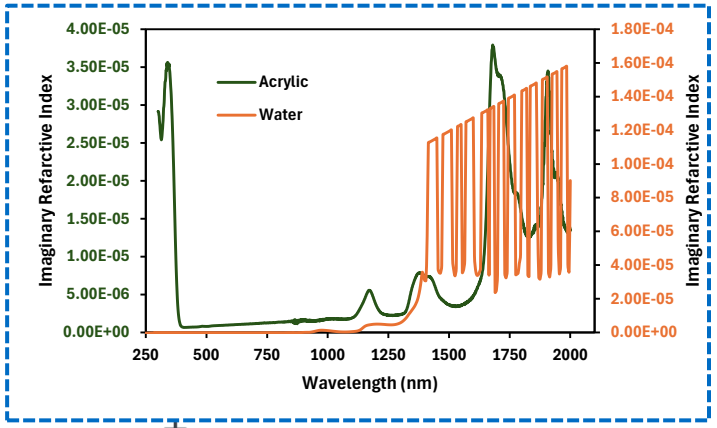


Fig. 5 Wavelength dependent imaginary refractive indices of water and acrylic calculated measured using UV-vis-NIR spectrophotometer.

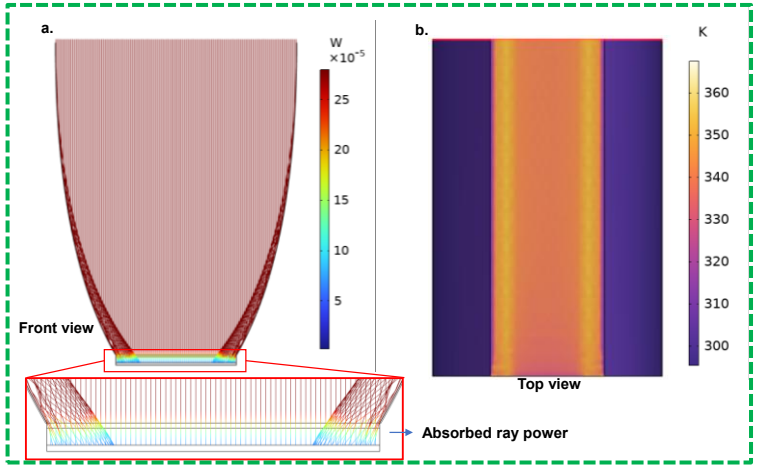
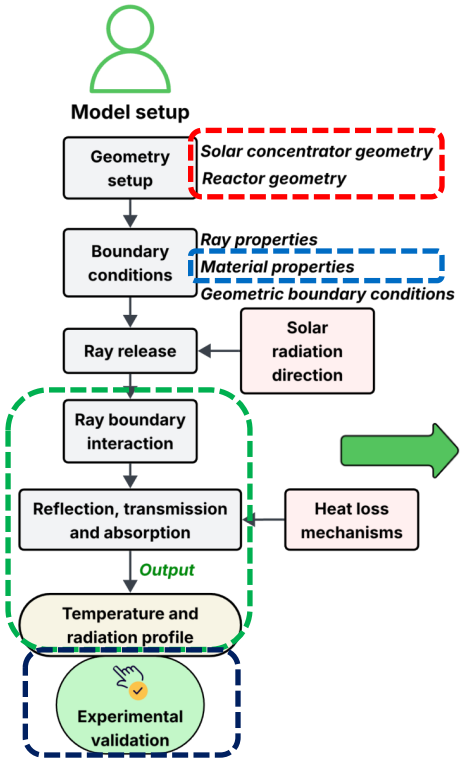


Fig. 6 a. Ray power absorption and **b.** heat generation due to the energy absorbed by materials. Boundary condition: Direct radiation intensity = 1000 W/m2, CR = 2, wind speed parallel to receiver plate = 3m/s, ambient temperature = 293.15 K. (Legend in Fig. S3a. shows the power (in Watts) corresponds to each ray as total power is distributed equally among each ray)



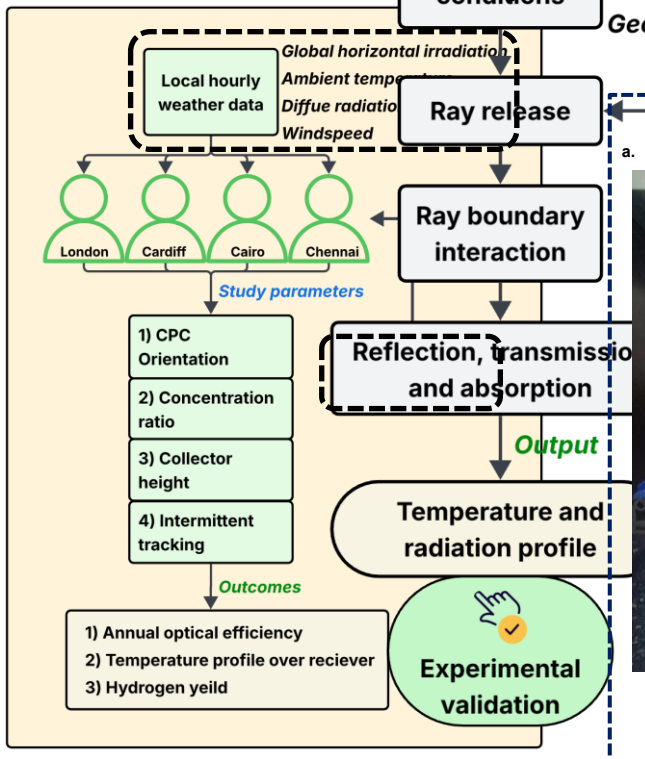


Fig. 3 Flowchart to simulate the temperature profile and solar radiation over reactor and involved study parameters and outcomes

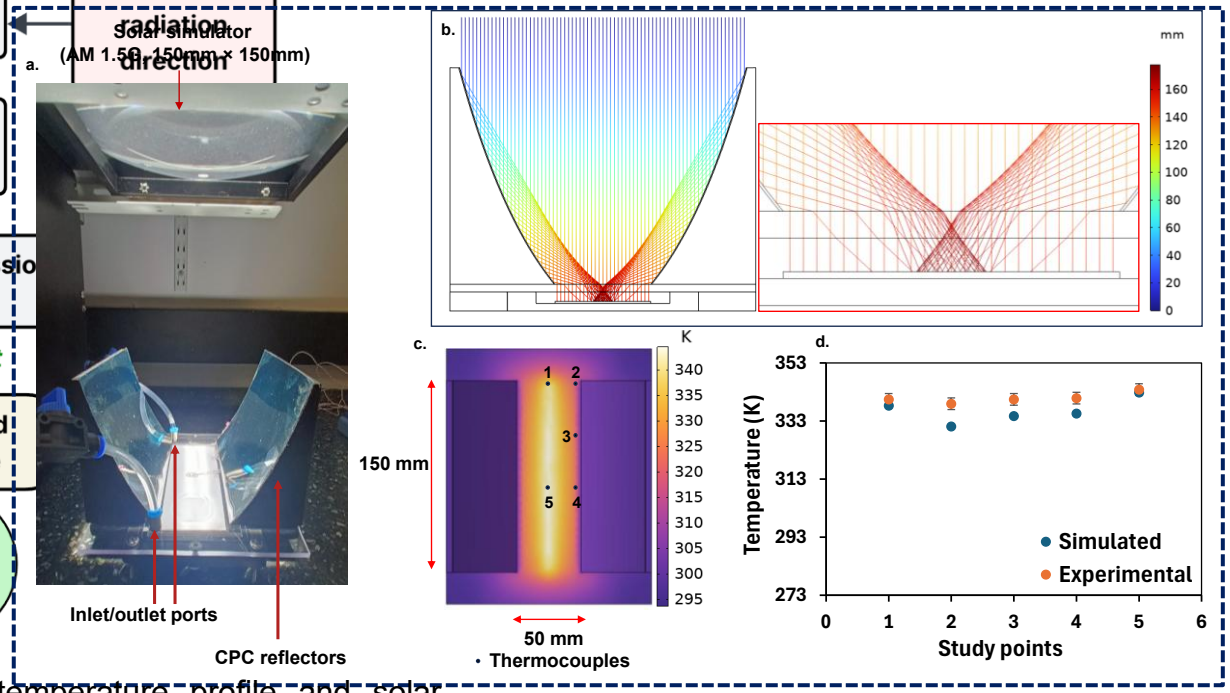


Fig. 7 a. Experiments conducted under solar simulator equipped with AM 1.5G filter for validating the computer model developed, **b.** Concentrated radiation profile over the reactor plate (legend: ray optical path length), **c.** Temperature profile generated and **d.** simulated and experimental results comparison.

Fig. 3 Flowchart to simulate the temperature profile and solar radiation over reactor and involved study parameters and outcomes

Modelling results

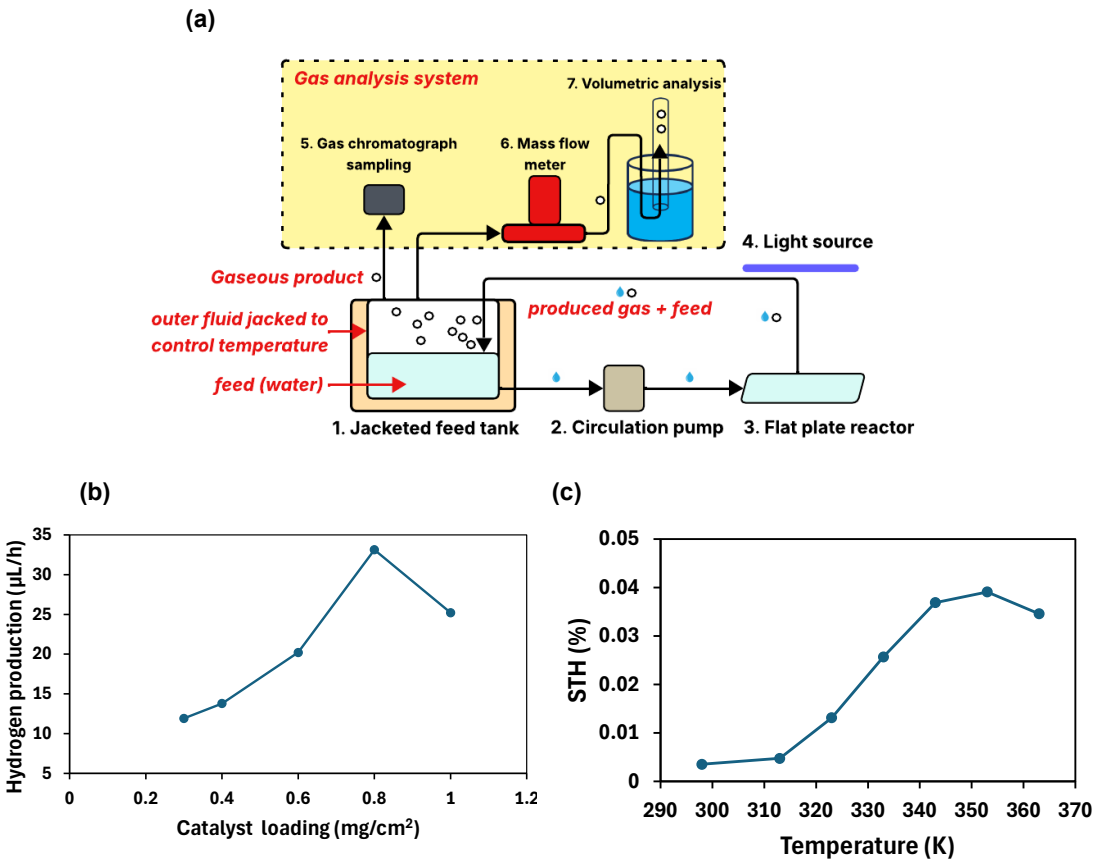


Fig. 8 a. Schematic of experimental setup, **b.** Hydrogen production at different catalyst loading at 323 K and **c.** STH efficiency at different operating temperatures at 0.8 mg/cm2 catalyst loading. Catalyst coated area = 75 cm^2

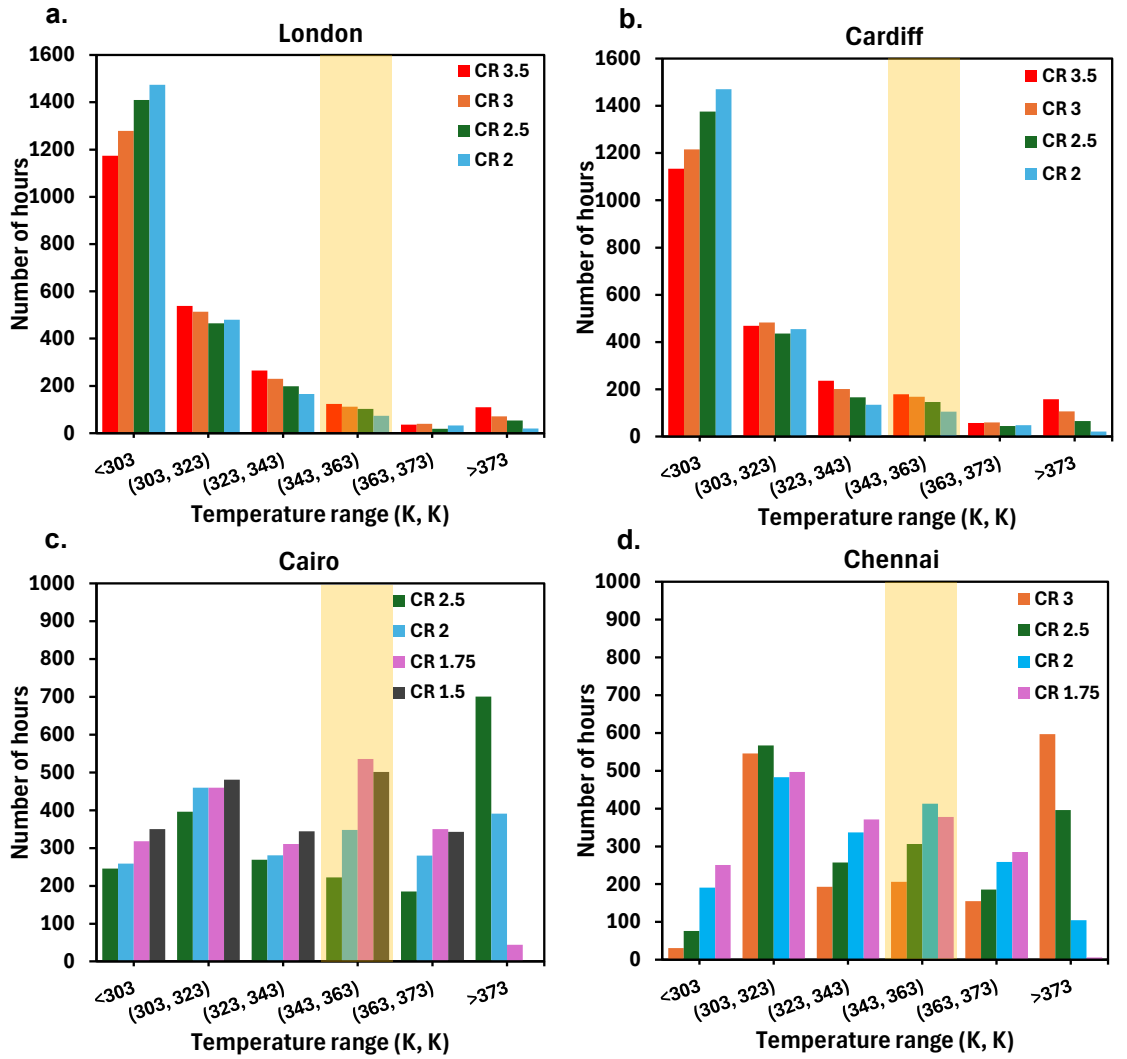


Fig. 9 Hourly temperature profiles at reactor plate for five peak summer months for **a.** London, **b.** Cardiff, **c.** Cairo and **d.** Chennai at different CRs.

Modelling results

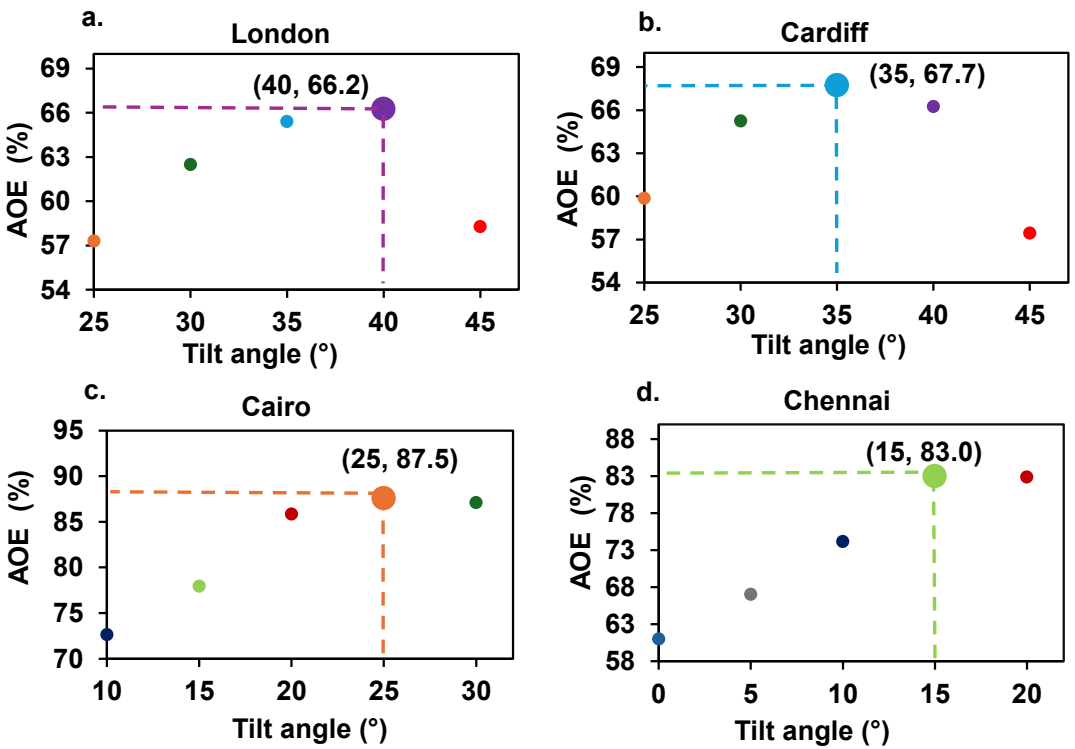


Fig. 10 AOE achieved at different tilt angles for corresponding starting CR for a daily operation from sunrise to sunset over the year for **a.** London, **b.** Cardiff, **c.** Cairo and **d.** Chennai.

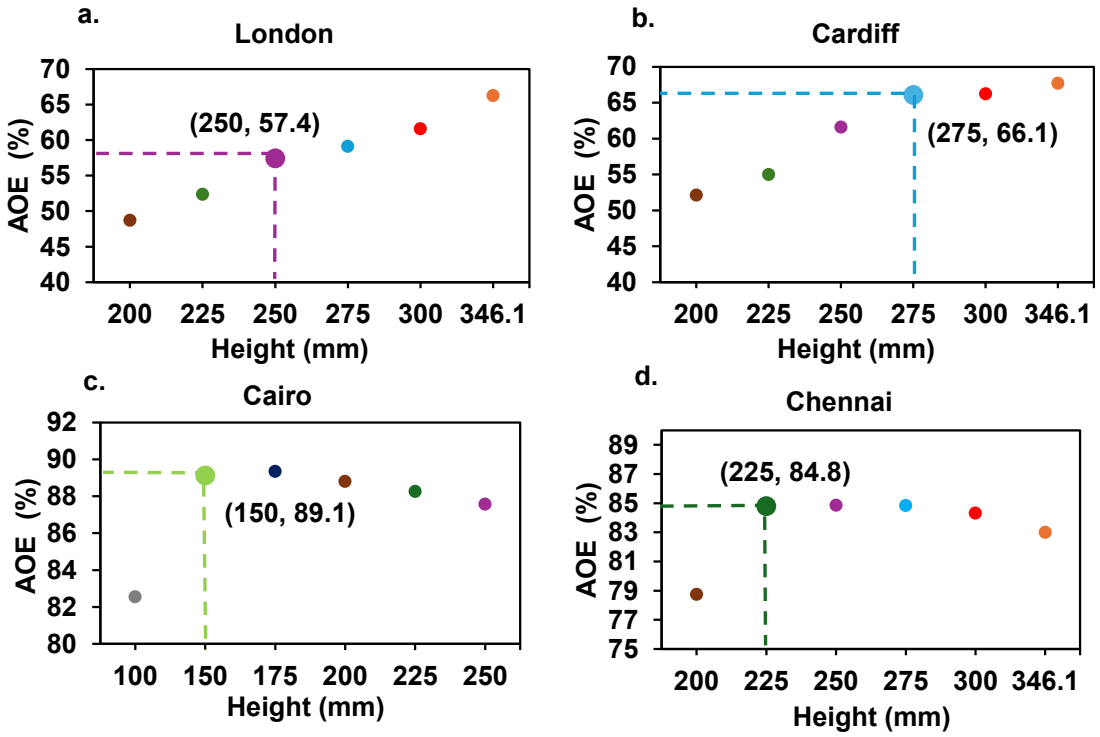


Fig. 11 AOE achieved at different CPC heights for corresponding optimum CR and tilt angle for a daily operation from sunrise to sunset over the year for **a.** London, **b.** Cardiff, **c.** Cairo and **d.** Chennai

Modelling results

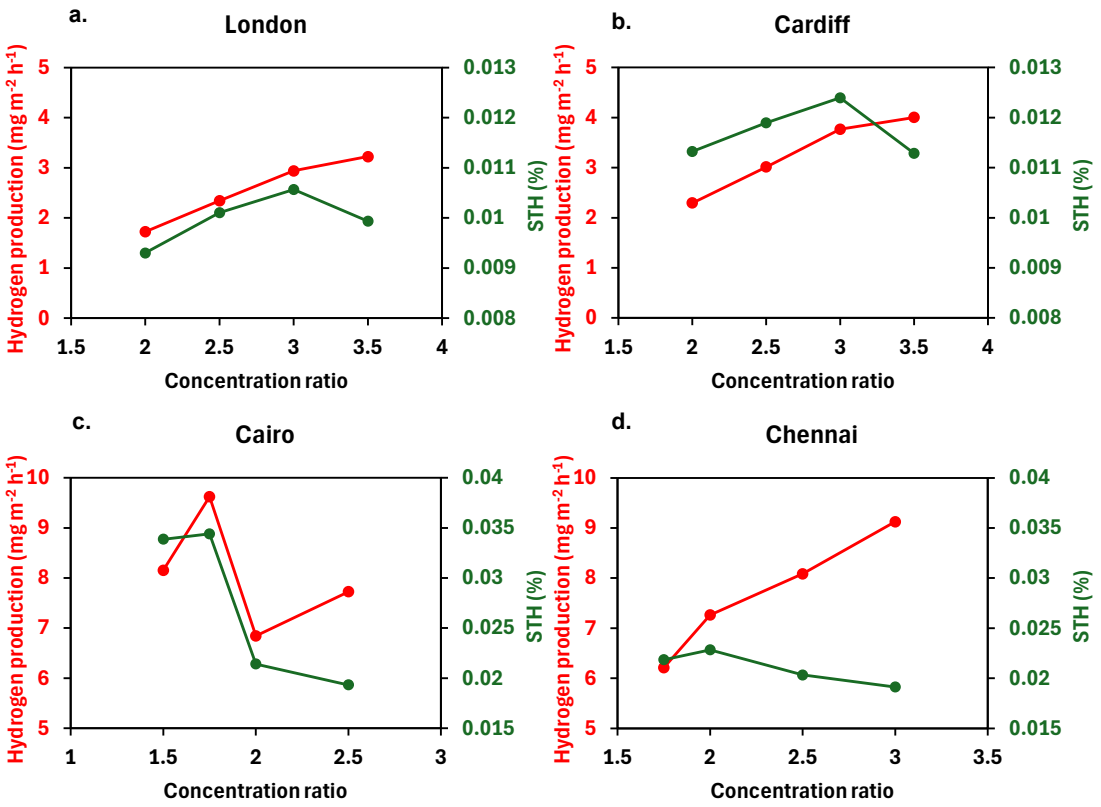
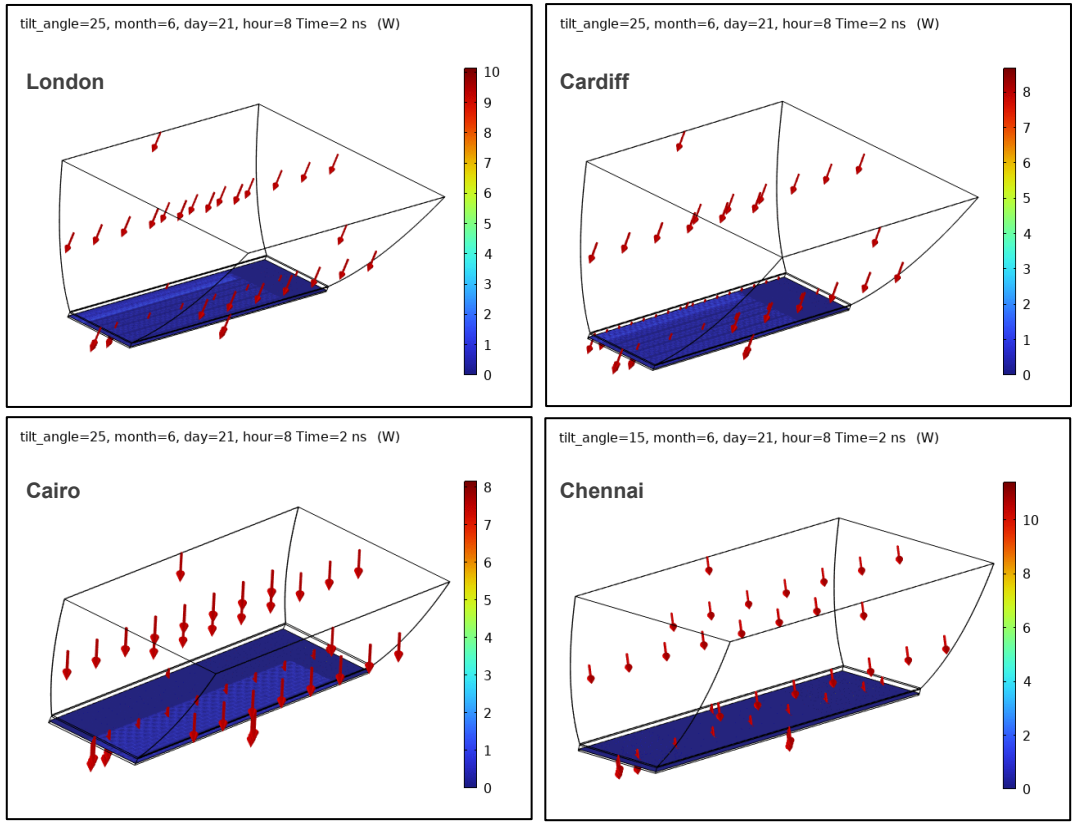


Fig. 12 Average hydrogen production rate per reactor area (red curves) and corresponding STH efficiencies (green curves) for five peak solar months at various CRs for **a.** London, **b.** Cardiff, **c.** Cairo and **d.** Chennai.



Movie. 1 Captured solar radiation over the receiver site accounting for hourly changes in solar trajectory on a reference day (21st June 2024) for **a.** London, **b.** Cardiff, **c.** Cairo and **d.** Chennai.
Arrow: Solar radiation direction, Legend: Normalized power of solar radiation

Reactor optimisation and outdoor tests under real life solar and climatic conditions

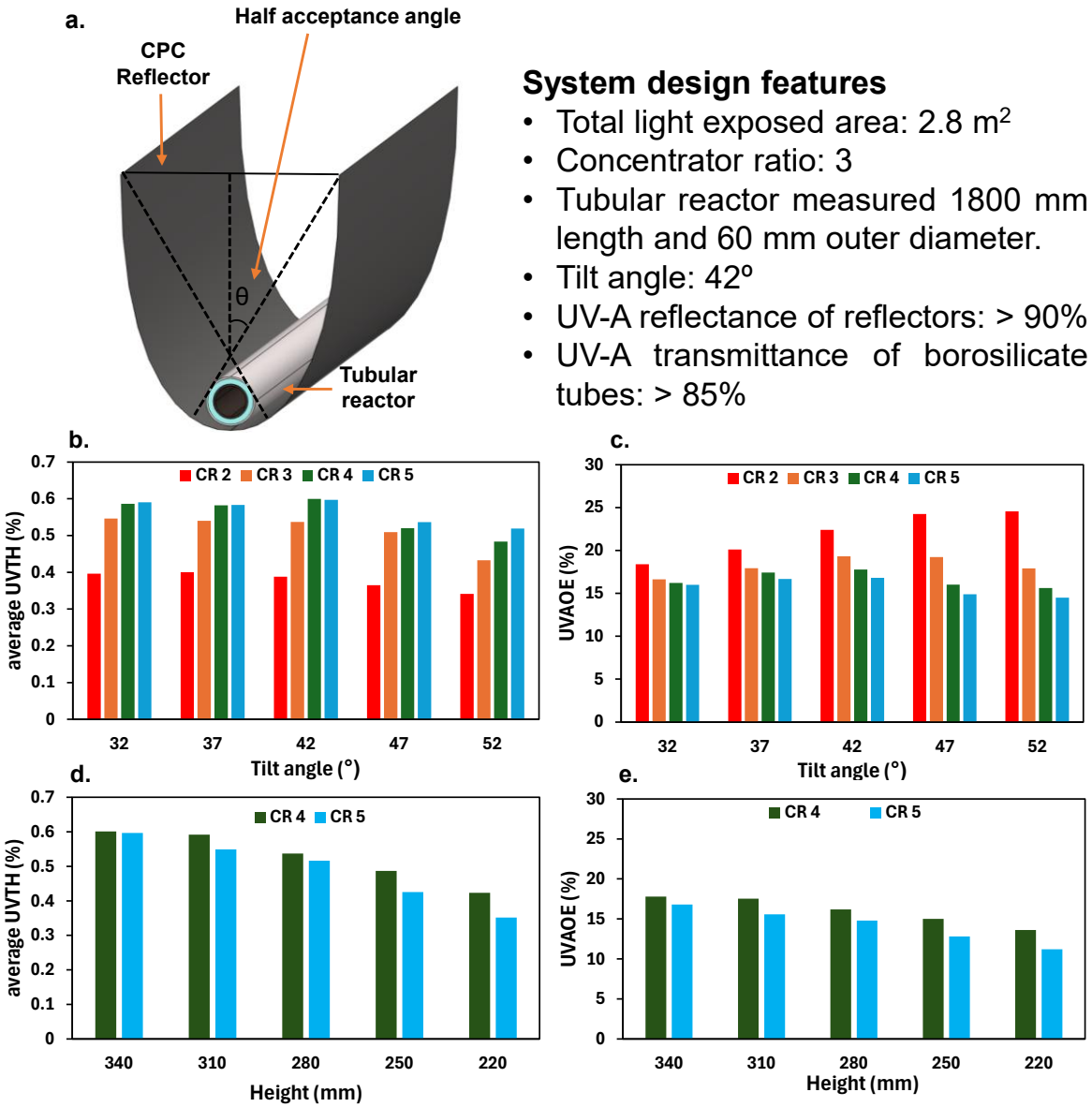


Fig. 13 a. CPC reflector integrated tubular reactor set-up. UVTH and AOE at various tilt angles b. and c. and at various CPC heights d. and e. for CPCs studied.

System design features

- Total light exposed area: 2.8 m^2
- Concentrator ratio: 3
- Tubular reactor measured 1800 mm length and 60 mm outer diameter.
- Tilt angle: 42º
- UV-A reflectance of reflectors: > 90%
- UV-A transmittance of borosilicate tubes: > 85%

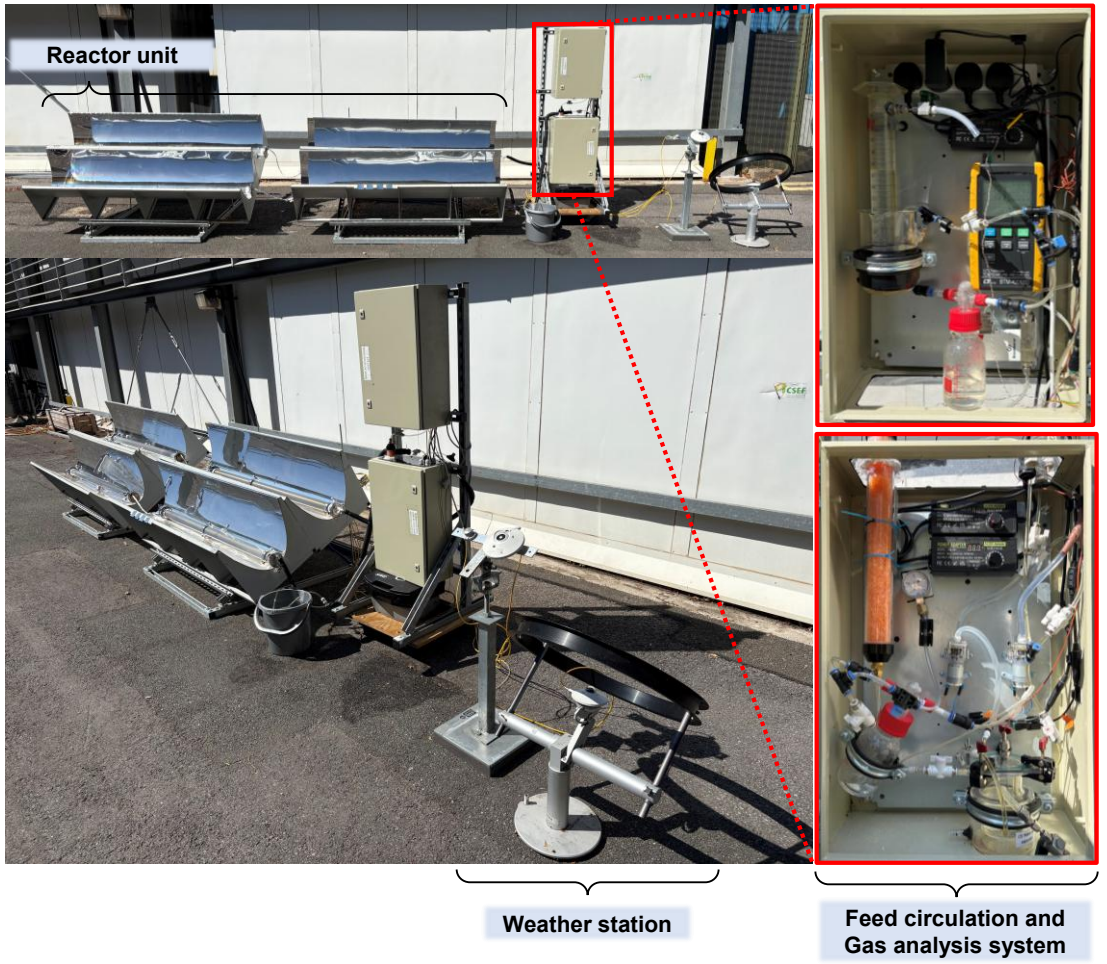


Fig. 14 Full scale outdoor setup installed at Brunel University of London (UK)

- Daily average hydrogen production rate **0.43 mg/m²/h**
- On 31st July 2026, the peak hydrogen production rate of **1.72 mg/m²/h** was recorded between 12:00 am to 02:00 pm at an operating temperature of **349.8 K**
- An average UVAOE of **46.85%** was predicted while operation under borosilicate tube.
- Average thermal efficiency of around **53.4%** was observed throughout the operation
- The average and maximum Kinetic Enhancement factor (KEF) of **6.91** and **17.9** times was observed throughout the operation which showed that solar concentrators can effectively utilise wide spectrum of solar radiation
- Reflectors showed stable **UV reflectance** throughout the operation

Summary

- Photocatalytic hydrogen production offers a clean, cost-effective solution to meet rising global energy demands by using sunlight to generate low-carbon fuel.

- We have developed a large-scale, 2.8m^2 aperture area, CPC assisted solar photocatalytic system which was installed and operated for prolonged duration under natural climatic conditions at Brunel University of London (UK).

- The system is able to efficiently harness wide solar spectrum; UV for photocatalysis and Vis-IR for photothermal effects.

- Although the STH efficiency remained low, the study successfully moves the technology forward from small lab tests to real-world outdoor applications.

- A validated predictive computer model was developed for evaluating catalyst performance and feasibility of hydrogen production saving iterative experiments, and accompanying costs, needed to optimise the reactor at pre-deployment stages.

- Lowering reactor costs requires using affordable, abundant, and stable catalysts like titanium dioxide.

Thank you for your attention!