Development of a polymer-carbon nanotubes based economic solar collector

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Outline

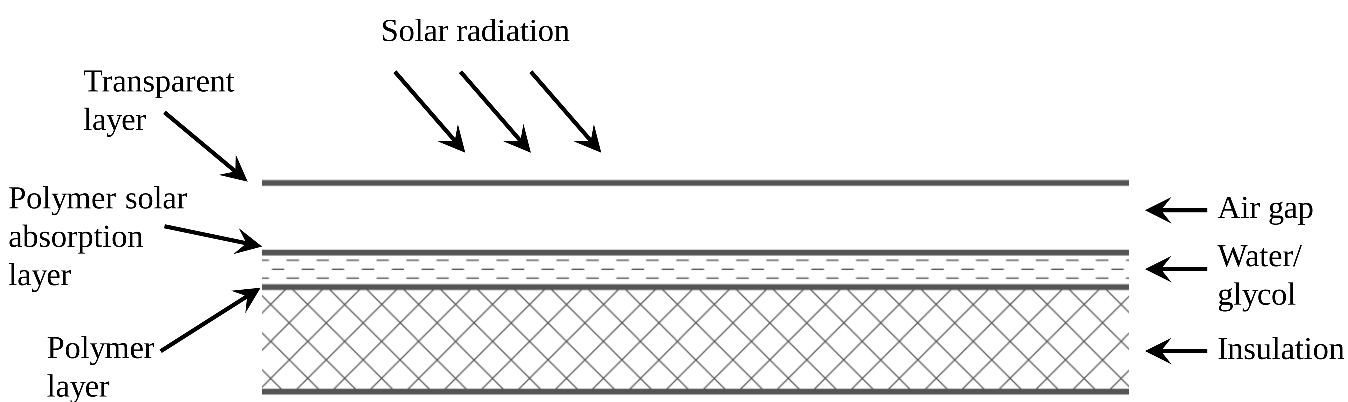
- Introduction
- Solar Collector Design
- Construction of prototypes
- Heat transfer analysis
- Tests results
- Production model
- Summary and Conclusion

Introduction

- Renewable energy for a sustainable energy future
  - Solar energy: solar collector, SWHS
- Conventional flat plate solar collectors
  - Metal absorber plate and glass cover
  - Significant total weight and cost, fragility of glass
- Cost effective solar collector
  - Polymeric components; transparent cover and radiation absorber

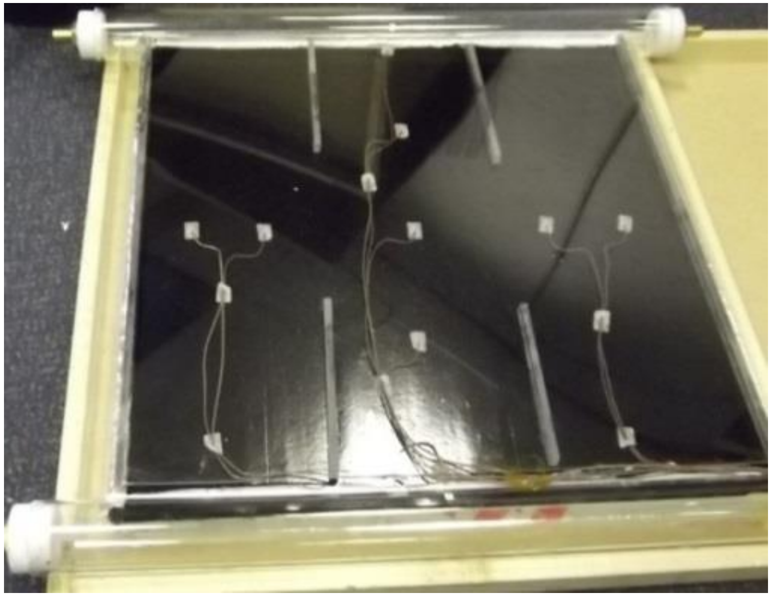
Collector Design

- Material selection
  - Improve low thermal conductivity of polymers
  - Inclusion of Carbon Nanotubes (CNT, 2000 – 6000 W/m·K)
  - Tests of radiation absorption, tensile and impact
- Multi-layer structure
  - A plastic glazing layer above air gap
  - Polymer+CNT absorbing layer above water
  - Polymer+CNT absorbing layer under water and then insulation foam



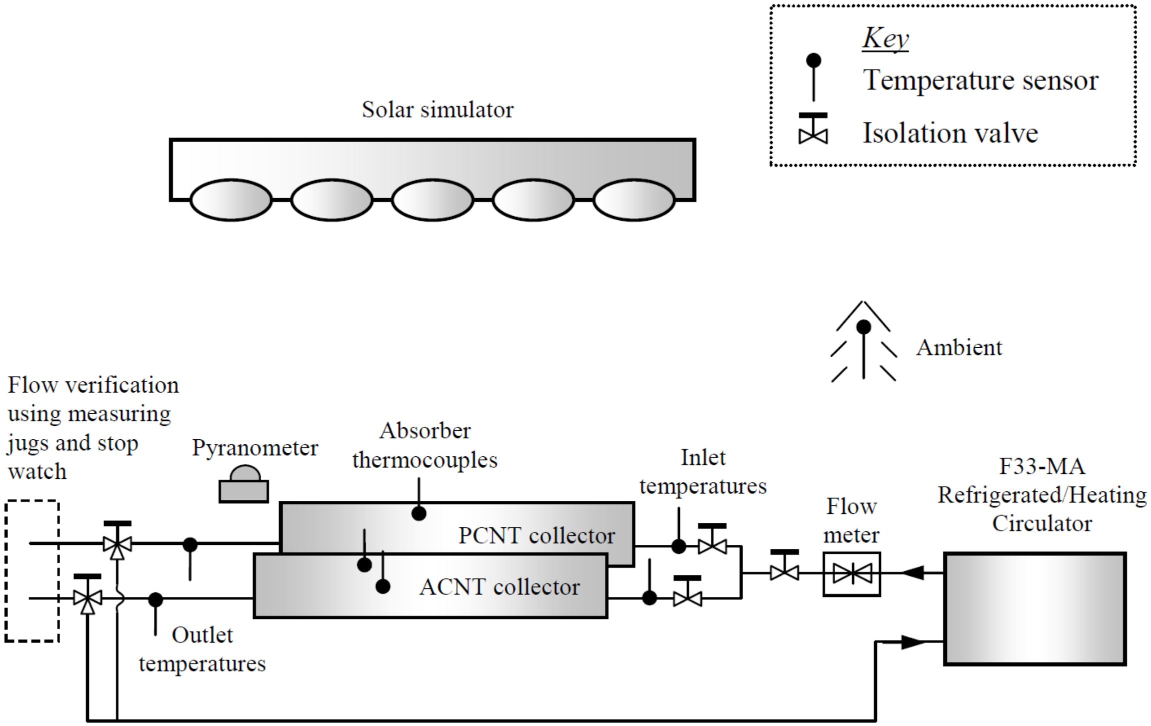
Construction of prototypes

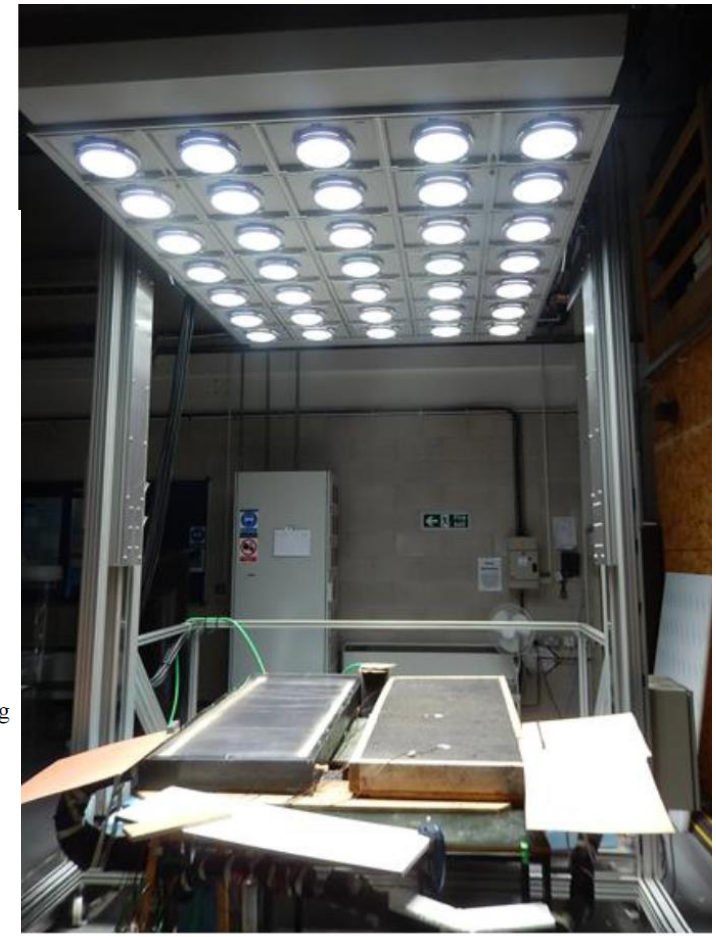
- The first prototype
  - 0.5 m × 0.5 m
  - Clear polycarbonate cover
  - Polycarbonate CNT absorbers



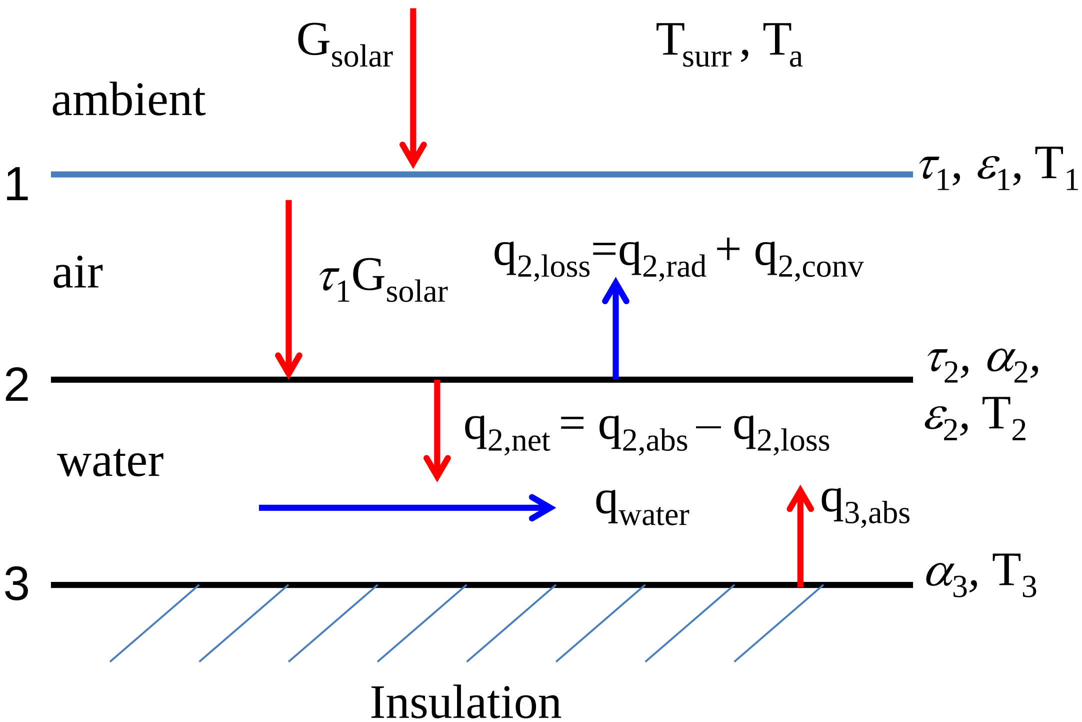
Test facility

- Centre for Sustainable Technologies, University of Ulster





Heat transfer analysis



$$q_{2,abs} = \alpha_2 \tau_1 G_{solar}$$

$$q_{3,abs} = \alpha_3 \tau_2 \tau_1 G_{solar}$$

$$q_{2,rad} = \frac{\sigma\left(T_2^4 - T_1^4\right)}{\dfrac{1}{\varepsilon_2} + \dfrac{1}{\varepsilon_1} - 1}$$

$$q_{2,conv} = k_{air} Nu \frac{T_2 - T_1}{H_1}$$

$$Nu = 1 + 1.44\left[1 - \frac{1708}{Ra}\right]^+ + \left[\frac{Ra^{1/3}}{18} - 1\right]^+$$

$$\boxed{\begin{aligned} &\therefore q_{2,net} + q_{3,absor} = \dot{m} c_p (T_{out} - T_{in}) / A_s \\ &\qquad \Rightarrow f(T_2) = g(T_{out}) \end{aligned}}$$

Performance estimations

(G_{solar} = 835W/m^2, T_a = 20°C)

T_{in} (°C)	T_{out} (°C)	q_{total}(W/m^2)	Efficiency
20	24.2	373	0.447
25	29.0	355	0.425
30	33.7	328	0.393
35	38.4	302	0.361

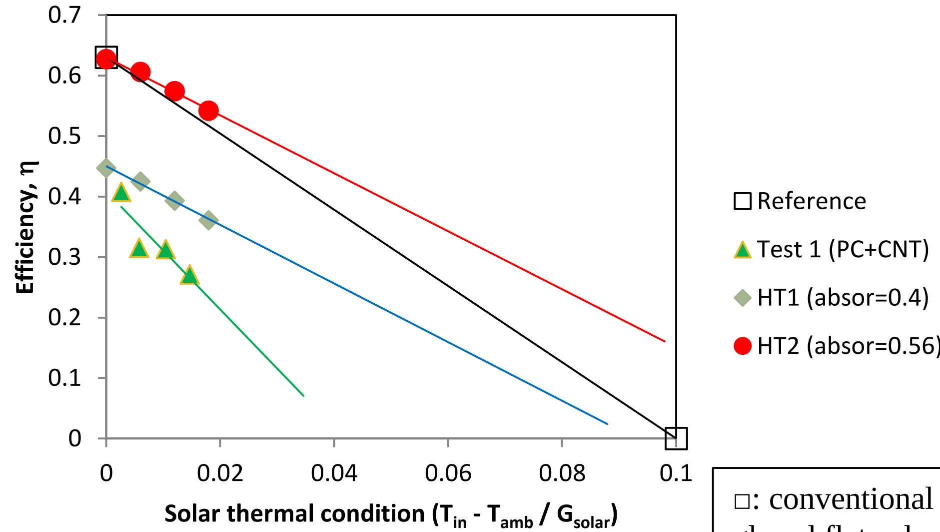
(HT1: 0.5m×0.5m, $\alpha_2 = \alpha_3 = 0.4$)

T_{in} (°C)	T_{out} (°C)	q_{total}(W/m^2)	Efficiency
20	25.9	524	**0.627**
25	30.7	506	**0.606**
30	35.4	479	**0.574**
35	40.1	453	**0.542**

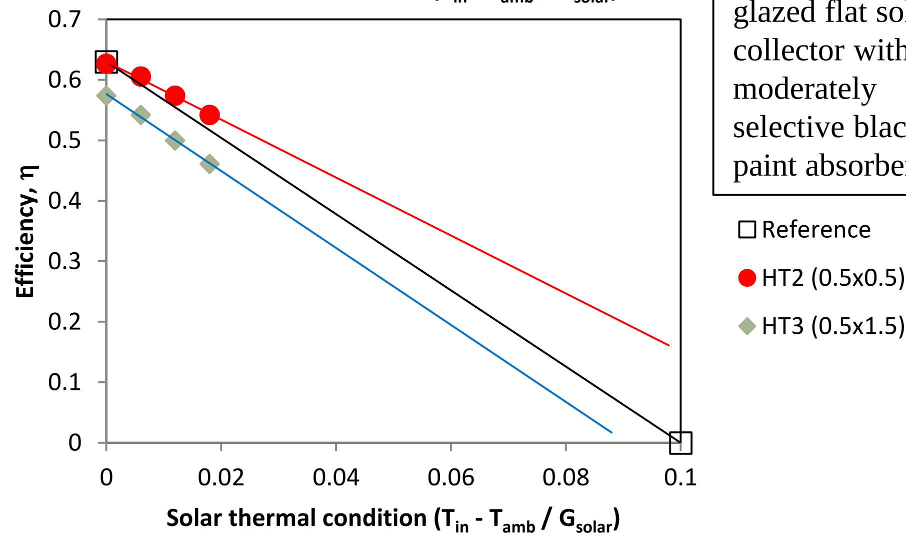
(HT2: 0.5m×0.5m, $\alpha_2 = \alpha_3 = 0.56$)

T_{in} (°C)	T_{out} (°C)	q_{total}(W/m^2)	Efficiency
20	**36.2**	479	0.574
35	**48.0**	384	0.461
45	**55.7**	317	0.379
55	**63.3**	246	0.294

(HT3: 0.5m×1.5m, $\alpha_2 = \alpha_3 = 0.56$)



□: conventional glazed flat solar collector with moderately selective black paint absorber



Construction of prototypes

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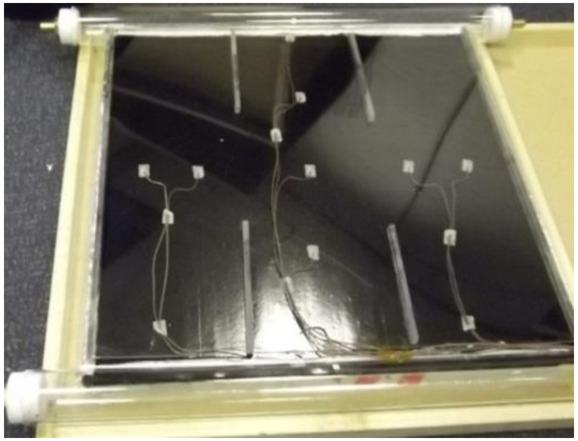
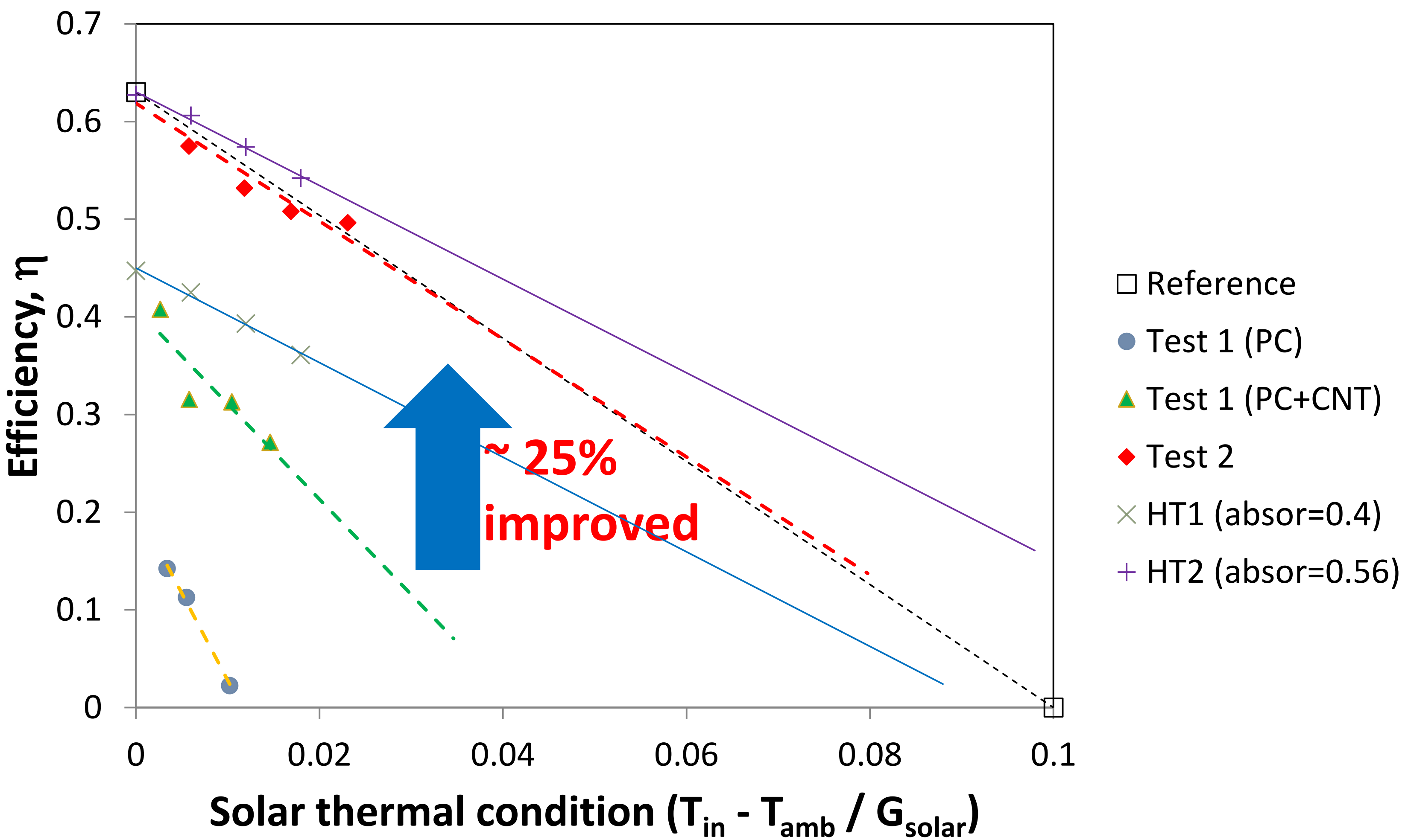


- The second prototype
  - Longer panel (longer water channel): 1.5 m × 0.5 m
  - Modified manifold (vents fitted) to remove entrapped air bubbles
  - Finishing the PC+CNT absorber surface (matted) to reduce the solar reflectivity and increase the absorptivity

Tests Results: Solar collector efficiency



Summary and Conclusion

- A multi-layer structure with considering the cost-effective manufacturing
- Good collector efficiency (> 0.6) and hot water outlet temperature (> 65°C) are estimated through heat transfer analysis.
- The inclusion of CNT improved significantly the performance of polymer absorber.
- Attractive and equivalent performance has been verified from the prototypes tests.
- The estimated cost of the production model is at least two times less than that of conventional collectors.
- Polymer-carbon nanotubes based economic solar collector has been successfully developed.