Assessing photovoltaic-thermal system performance across diverse climates: An economic and environmental comparative analysis

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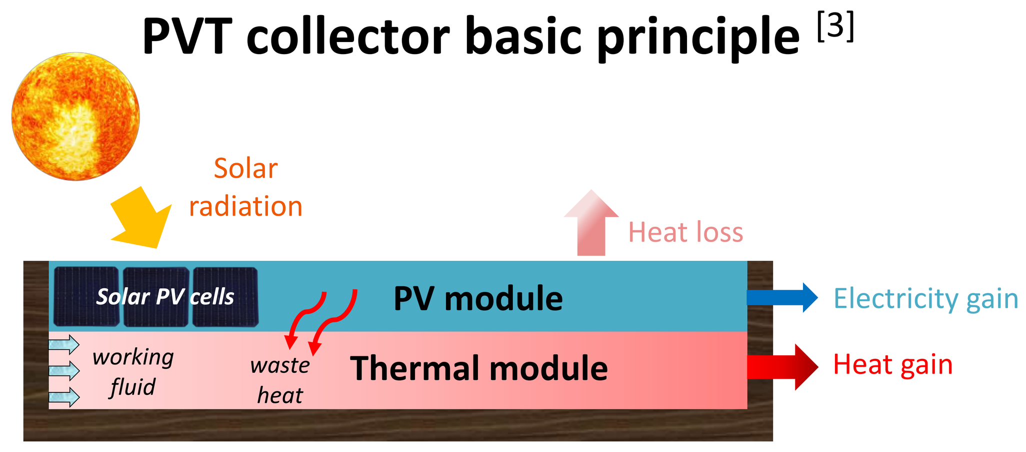
Motivation

- Photovoltaic-thermal (PVT) systems generate both **electrical** and **thermal energy simultaneously** [1], enhancing efficiency and longevity of PV cells.
- Introduction of **dynamic models** for air-based and bi-fluid based PVT collectors.
- Highlighting PVT collector adaptability to different **climate zones** [2], ensuring effective solar energy utilization in diverse regions.
- These collectors significantly **reduce CO_2 emissions** compared to traditional PV modules, demonstrating superior **environmental performance**.
- Assessing the **economic feasibility**.

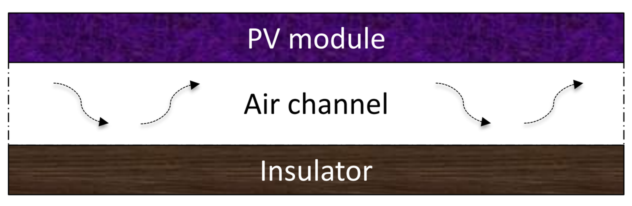
PVT collector basic principle [3]



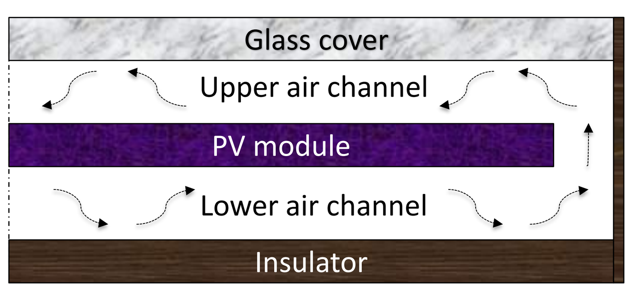
Modelling PVT collectors

- Developed **dynamic models** for different PVT collectors [3].
- Determined governing equations using **energy conservation principle**.
  - Applied at each component of the collector.
  - Considering **heat exchanges** between the layers.
- Several **assumptions** were considered.
  - Homogeneous temperature for each component.
  - Neglecting edge and bottom losses.
  - Overlooking pressure losses and partial shading.

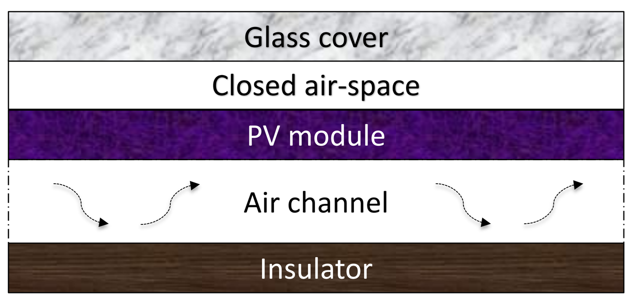
Unglazed air-based PVT



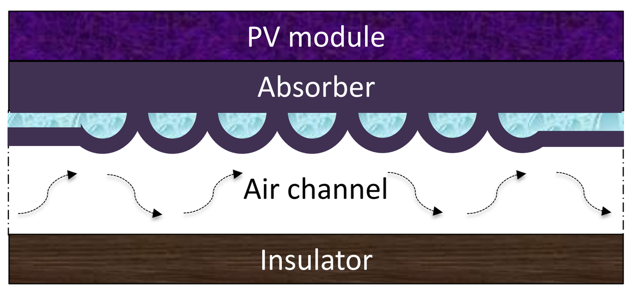
Glazed air-based PVT



Dual channel air-based PVT

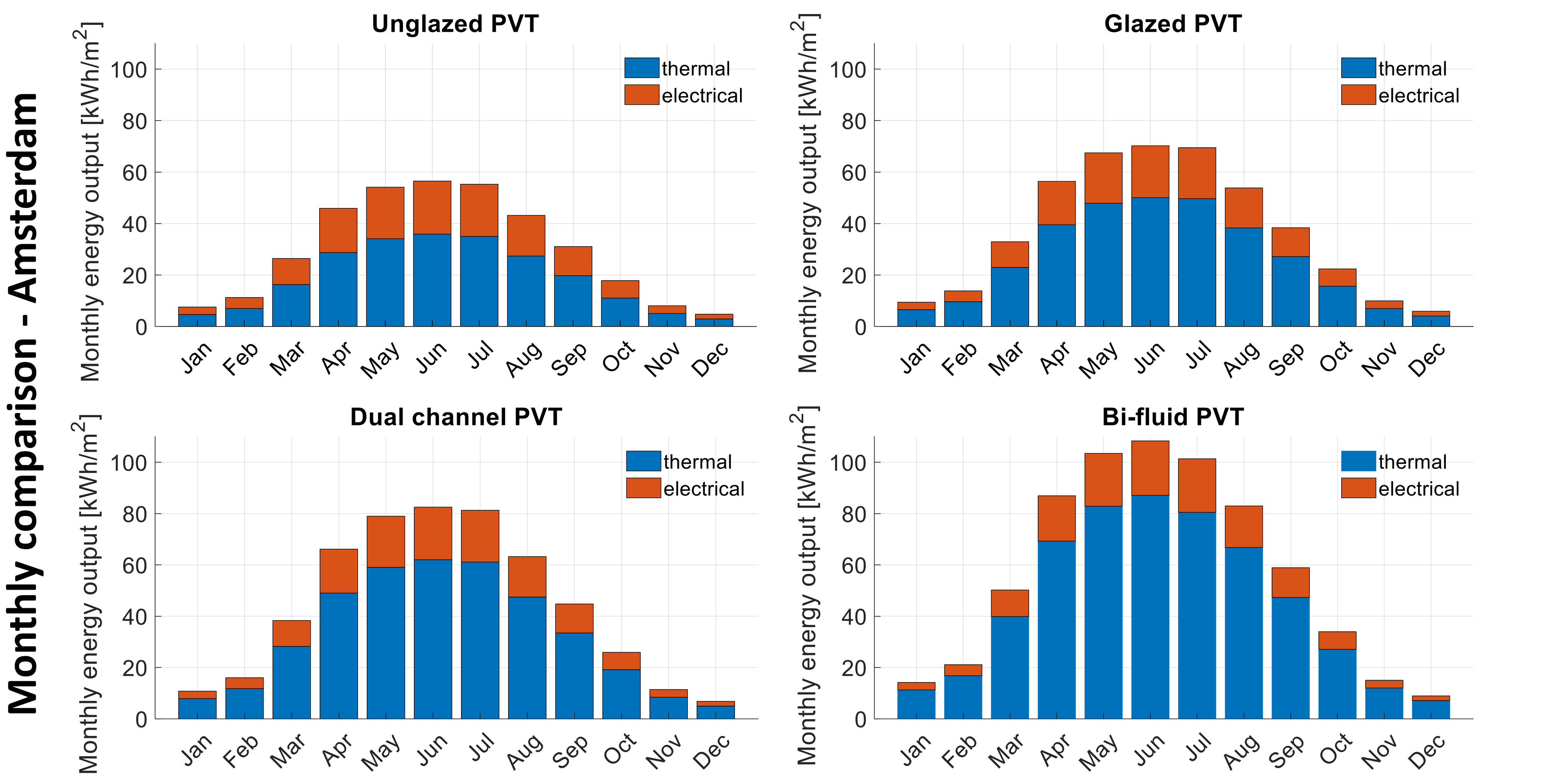


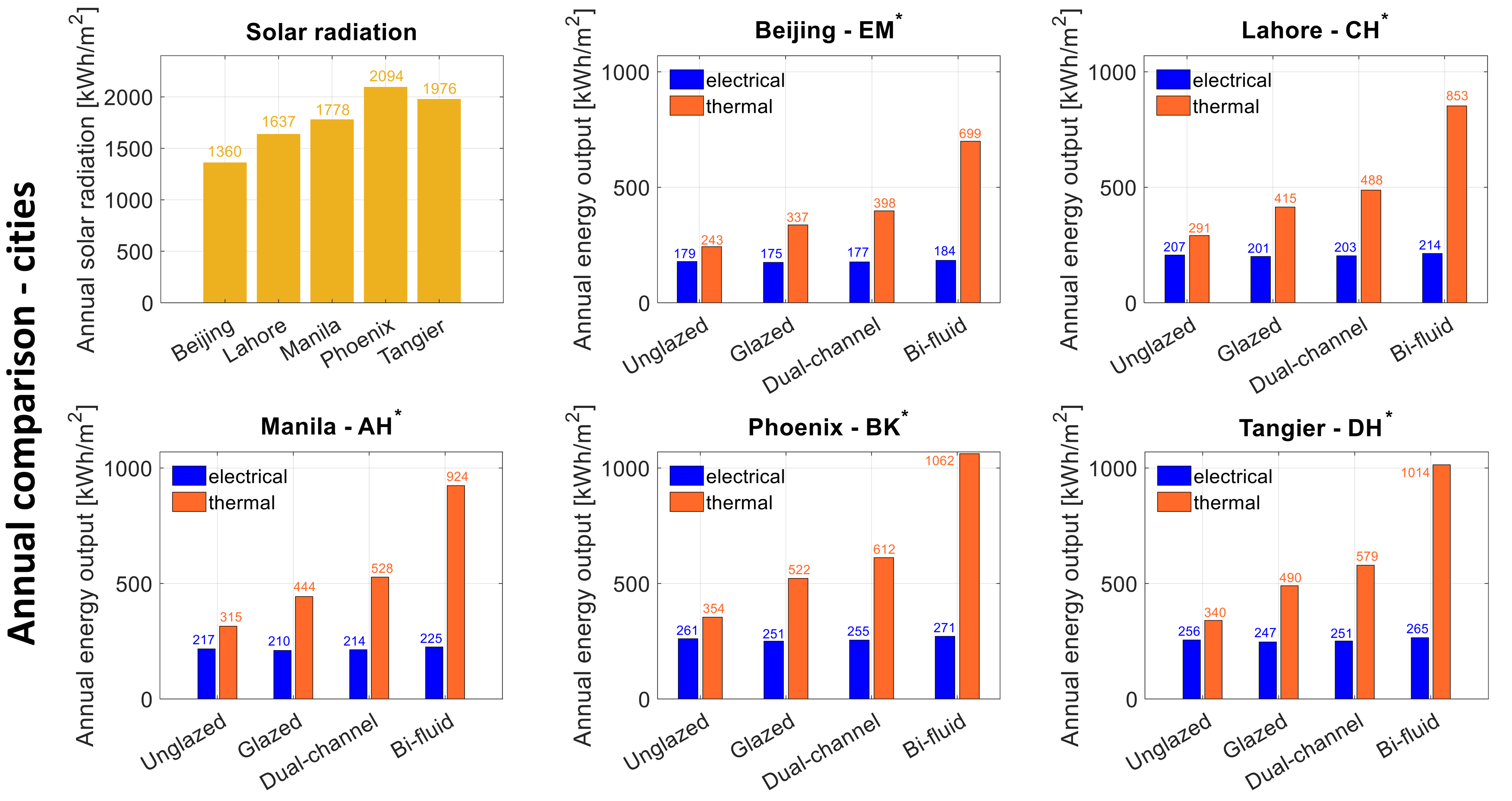
Bi-fluid PVT



Energetic performance analysis

- Six cities representing **different climate zones** were chosen from northern hemisphere.
- Each corresponds to specific climate zone based on **temperature-precipitation** and **irradiation** [2].
- Weather data from **Amsterdam** as input for monthly comparison.
  - Monthly irradiation varies from 15 kWh/m² (December) to 158 kWh/m² (June), giving an **annual irradiation of 1018 kWh/m²**.
  - Monthly **average temperature** varies between **3.3 °C** (January) and **18.6 °C** (July).



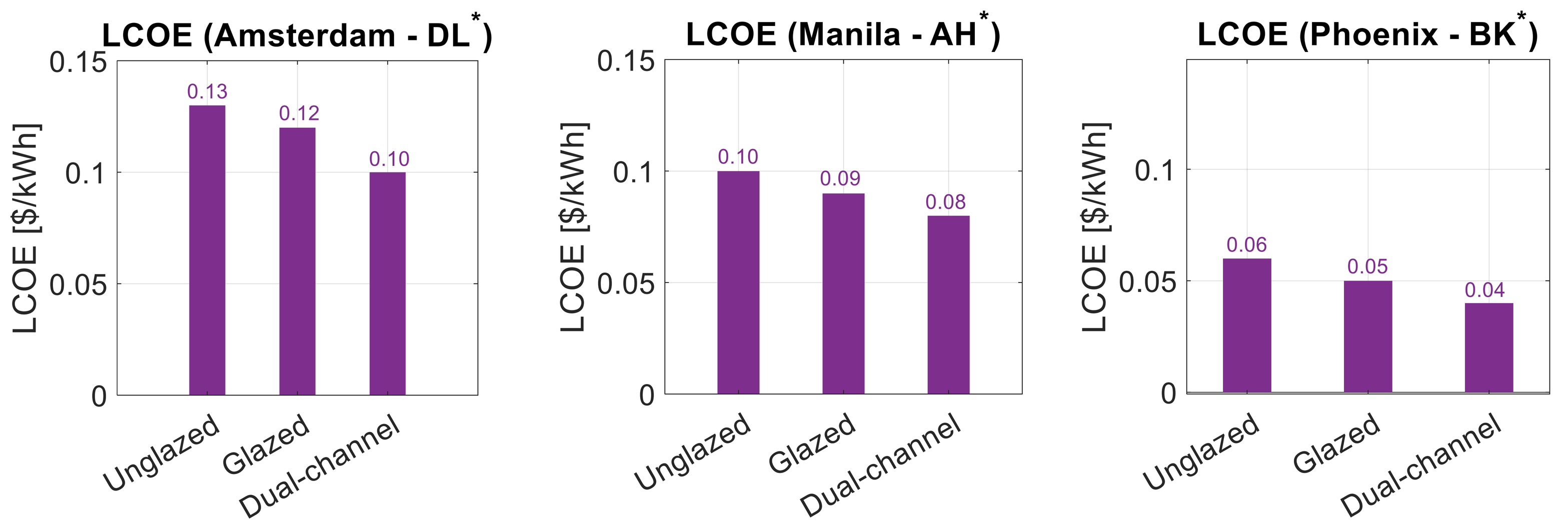


*First letter indicates Temperature Precipitation ➡ A – Tropical, B – Desert, C – Steppe, D – Temperature, and E – Cold.
Second letter indicates Irradiation ➡ H – High, K – Very High, and M – Medium.

Economic and environmental analysis

- Levelized cost of electricity (LCOE) is calculated by **combining** annual electrical and thermal yield [4].
- Environmental analysis involves modules with a **surface area** of approximately 0.50 m².
- Total electrical equivalent energy production is calculated using **thermal power plant conversion factor** of 0.38 [5].

Comparison of LCOE



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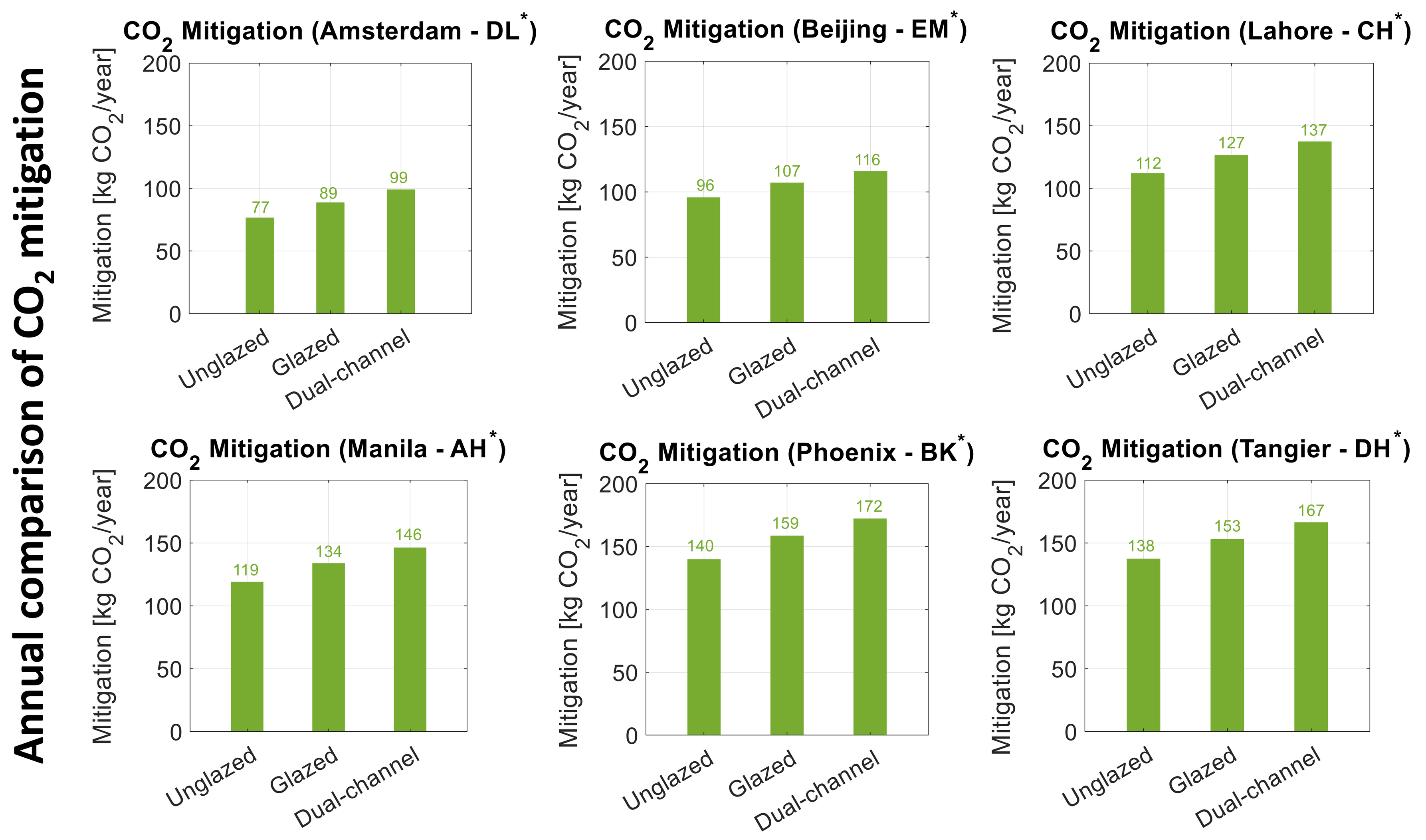

Conclusions

- Unglazed PVTs are **optimal for PV cooling**, while dual-channel PVT **excel in air heating**.
- Using two different fluids simultaneously **boosts thermal output** and **effectively cools PV cells**.
- Lower LCOE for **dual-channel PVT** is due to the additional thermal energy.
- PV unit **avoids emissions** at a minimum of 47 $kgCO_2$/year, while PVTs avoid a maximum of 140, 159 and 172 $kgCO_2$/year.

References

[1] Z. Ul Abdin, & A. Rachid, **2021**, Energies, 14(4), 1205.
[2] J. Ascencio-Vásquez, et al., **2019**, Sol. Energy, 191, 672-685.
[3] Z. Ul-Abdin, et al., **2024**, Sol. Energy, 276, 112687.
[4] J. Dijkstra, **2024**, MSc thesis, TU Delft.
[5] W. He, et al., **2006**, Appl. Energy, 83(3), 199-210.

Acknowledgements

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