Impact of BIPV window on building energy consumption and urban microclimate: Model development and sensitivity analysis

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Problem Statement

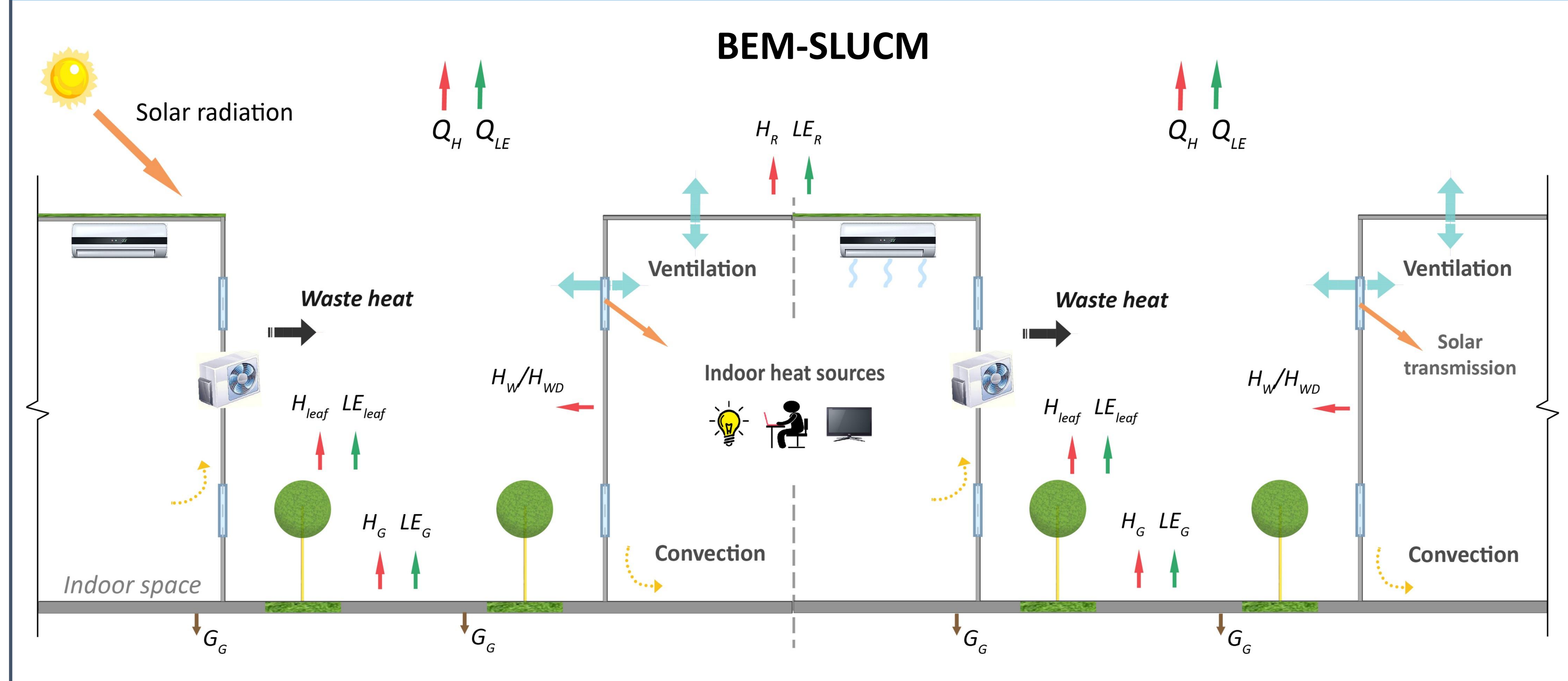
Building-integrated photovoltaic technology (BIPV) has been proven as an effective way to increase renewable energy and achieve low-carbon in the urban environment. Due to the lack of modelling tools, the impact of BIPV window in the street canyon has not yet been well understood.

To fill the gap, we developed a new parameterization scheme for BIPV window, and incorporated it into building energy simulations coupled with a single-layer urban canyon model. Sensitivity studies are conducted to reveal the impact of BIPV window in urban setting in three Chinese cities.

Research Questions

1. What is the impact of BIPV window on the building energy consumption and urban microclimate?
2. What are the key parameters to control the performance of BIPV window?
3. What is the potential of BIPV window in the cities under different climate zones?

The Coupled Building Energy Model and Single-Layer Urban Canopy Model



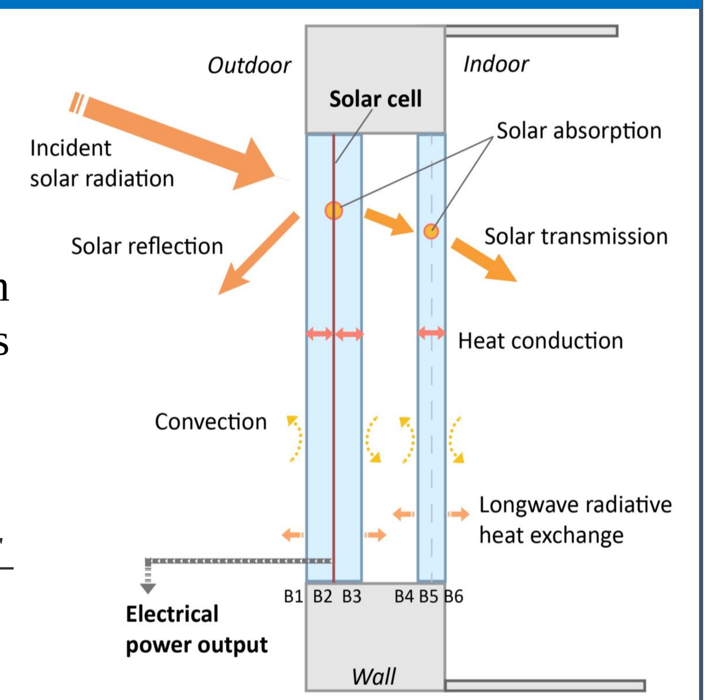
UCM and BEM are two-way coupling

BIPV window parameterization scheme

Assumption:

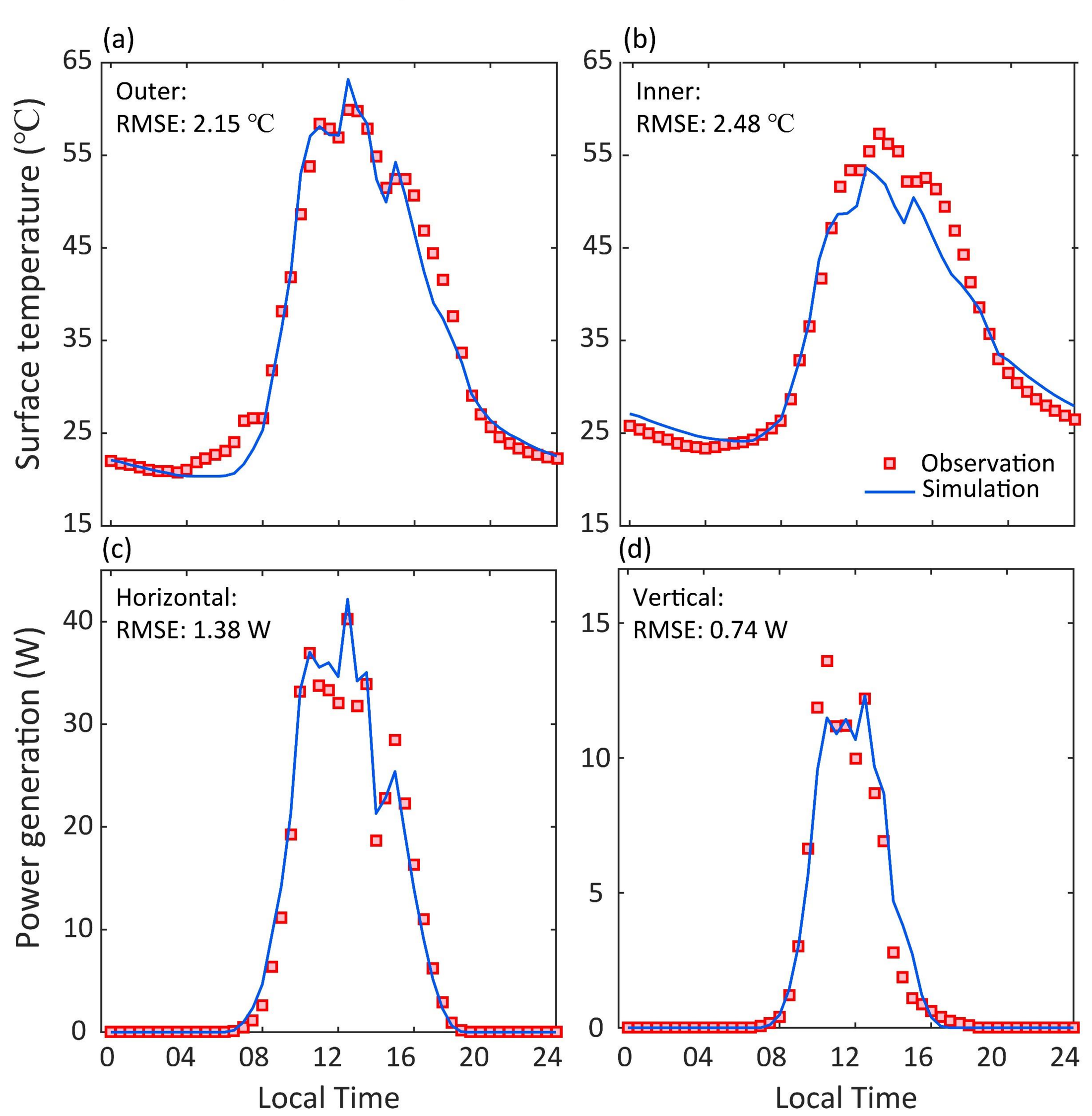
- Six-boundary BIPV window system
- One-dimensional cross-section heat flow
- Thermal storage happens at a thin layer in the middle of front and rear panes (boundaries B2&B5)

$Power \propto Radiation \times Transmittance \times ...$
$Efficiency \times Incident\ angle\ modifier$



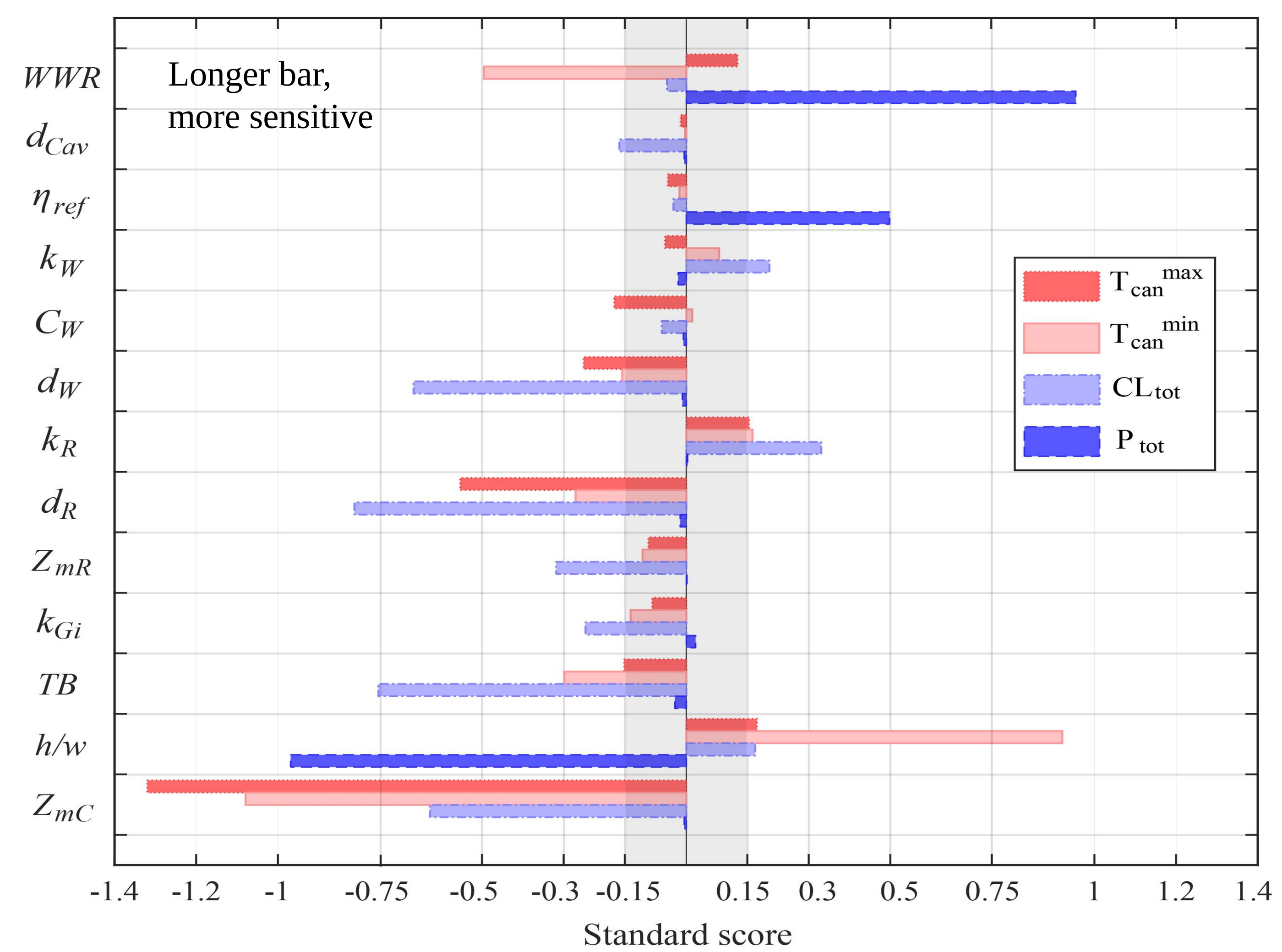
Model Evaluation

I) Energy exchange through window (v.s field measurement in South Korea)
II) Building energy consumption (v.s. EnergyPlus in Phoenix and three Chinese cities)
III) Urban microclimate (v.s Eddy Covariance tower data in Phoenix, Arizona, US)



Comparison of observed and simulated surface temperature and power profiles of BIPV window

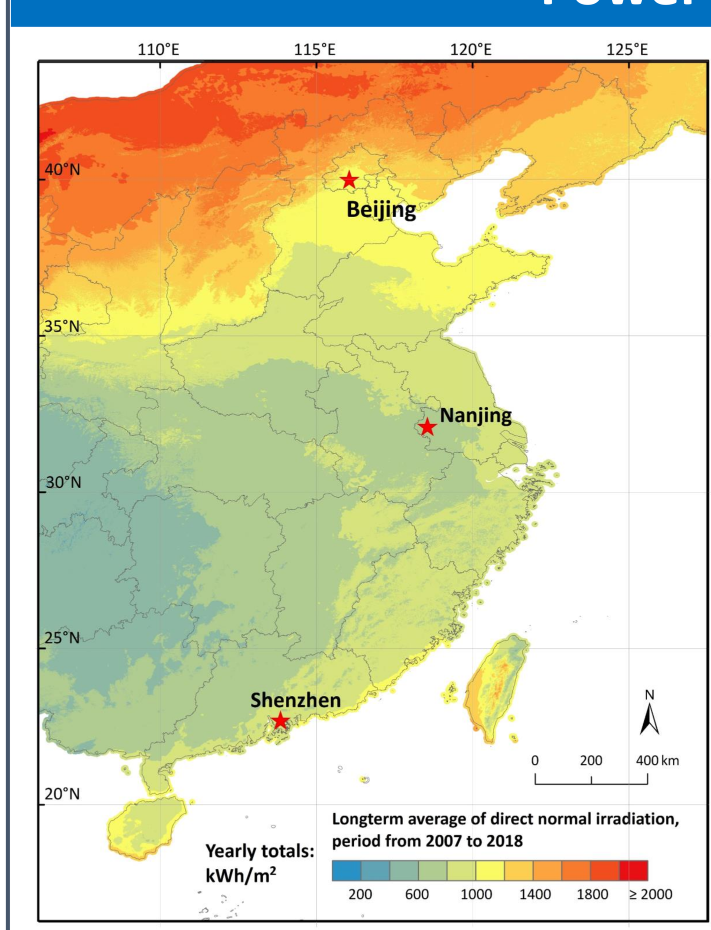
Sensitivity of Monitored Output to Parameters

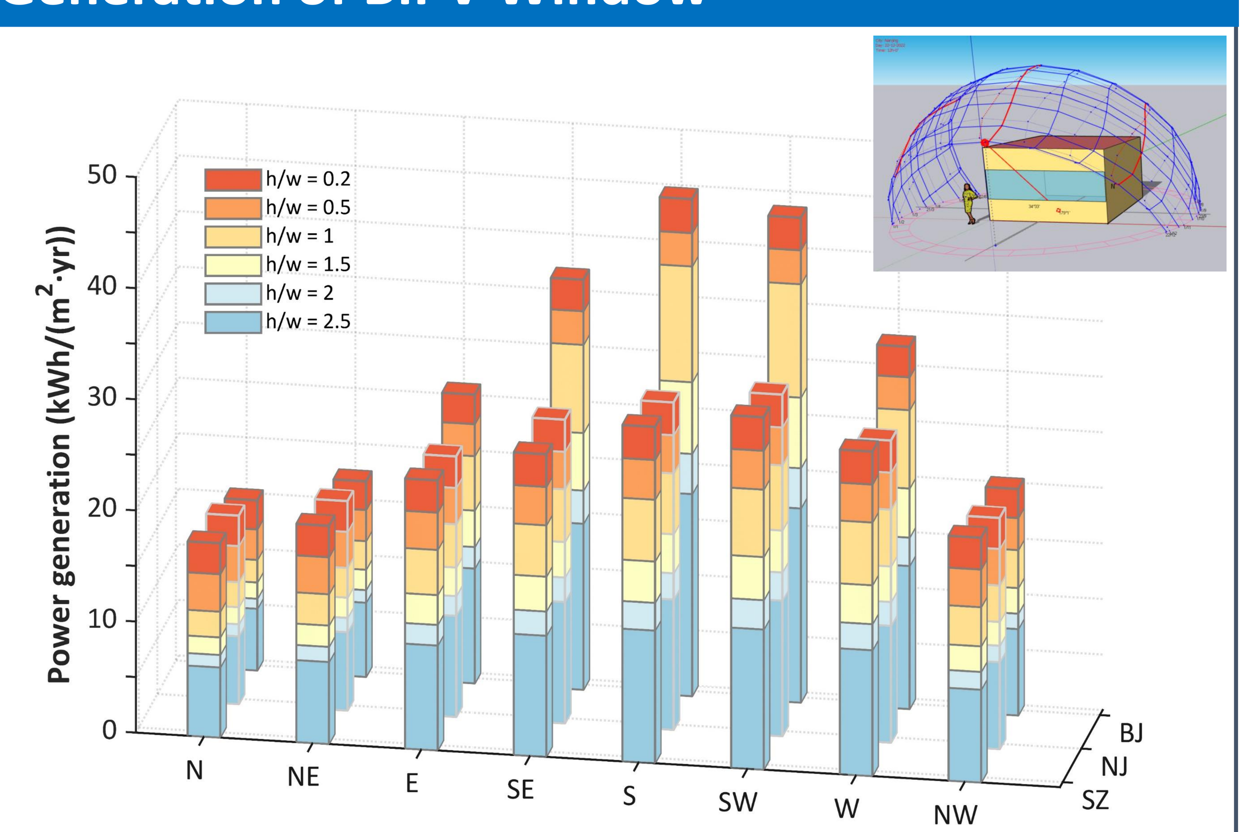


Key parameters:
1. Window-to-wall ratio
2. Power generation efficiency
3. Canyon aspect ratio
4. Façade orientation

Standard score of sensitive parameters for monitored output T_{can}^{max}, T_{can}^{min}, CL_{tot}, and P_{tot} on a clear summer day in Phoenix.

Power Generation of BIPV Window

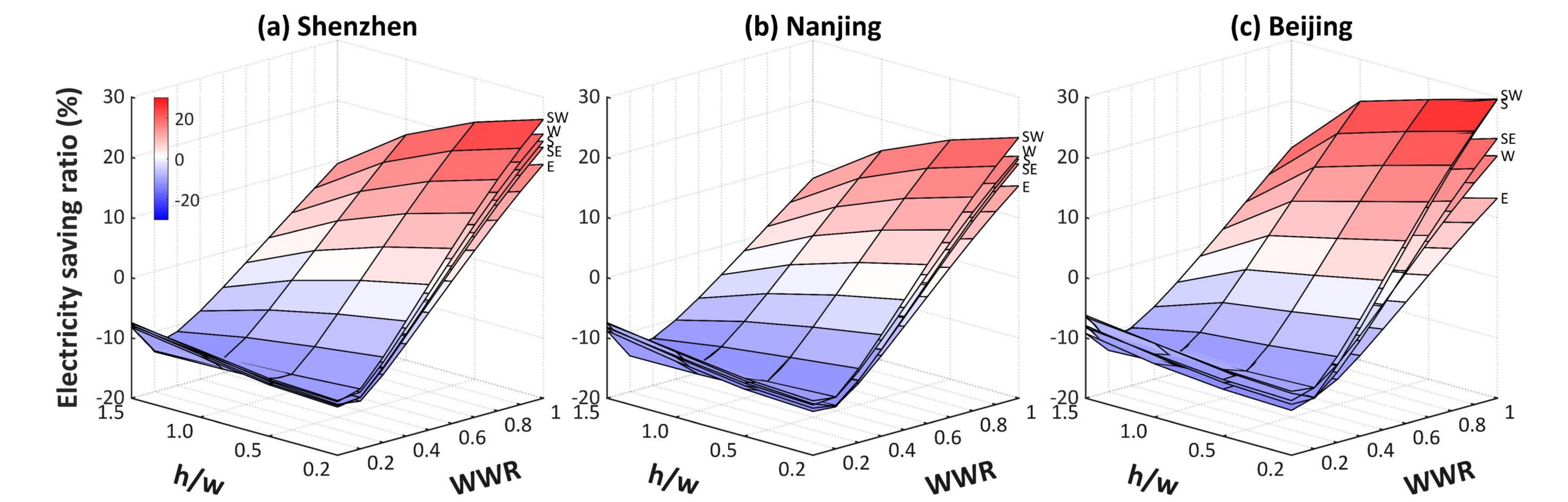




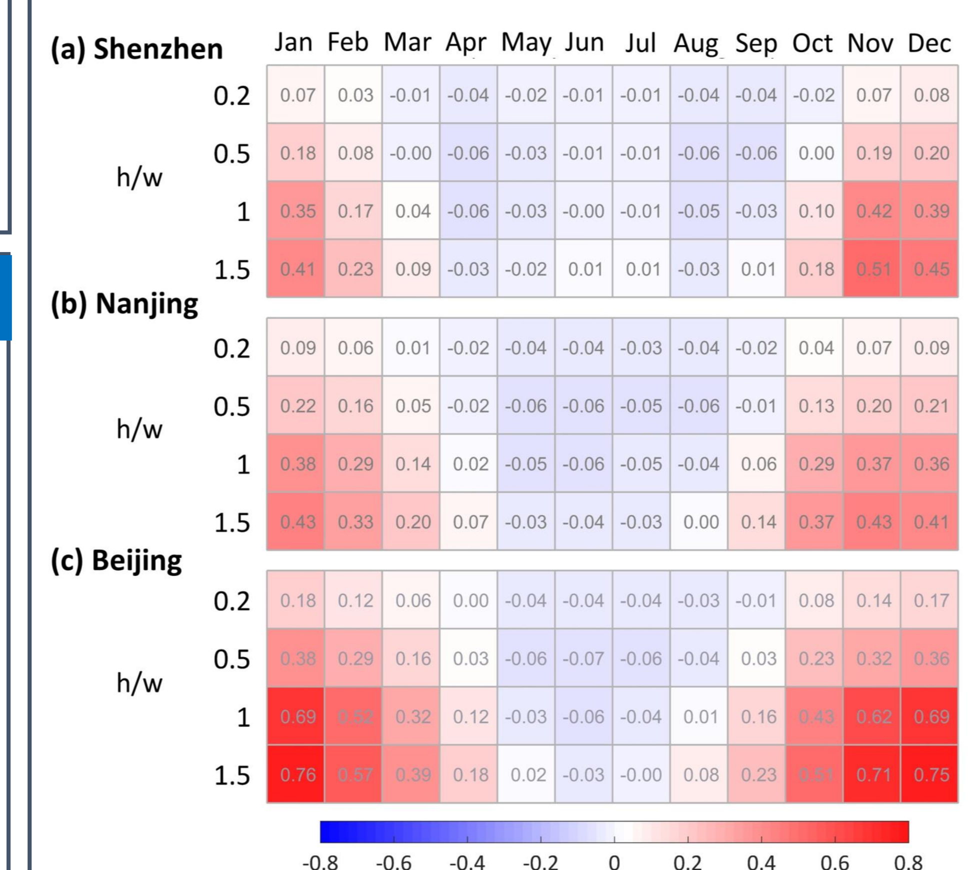
Power generation efficiency: BJ > SZ > NJ

Impact of BIPV Window

Compared to clear window:



BIPV energy benefit is larger for open canyons with large window coverage and facing Southwest.

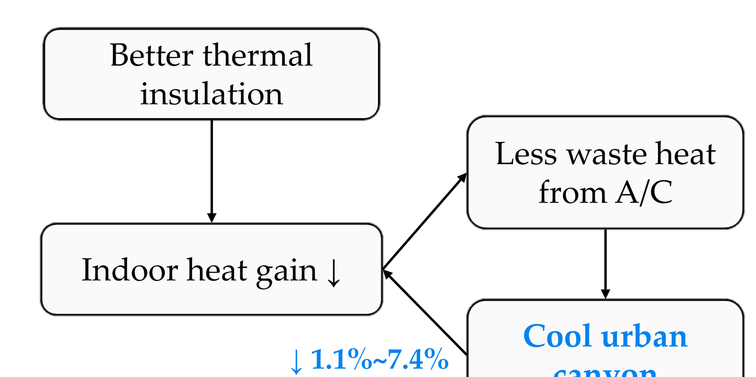


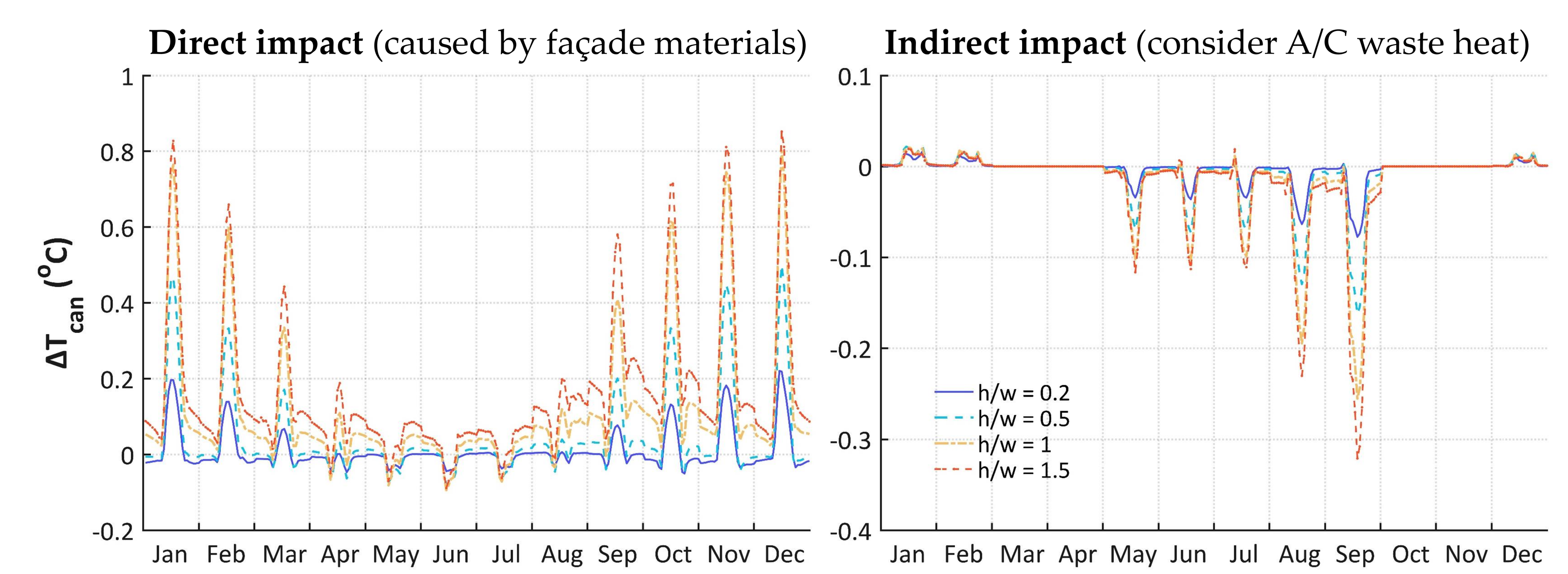
Impact on monthly average daytime T_{can}:

Summer: very slight cooling effect

Winter: warming effect of 0.1 ~ 0.8 °C

BIPV windows can enhance outdoor thermal comfort





Conclusion & Perspective

- With incorporation of BIPV window scheme into BEM-SLUCM, the model can investigate how BIPV window affects a fully interactive built environment.
- The performance of BIPV window in urban setting are most sensitive to variable: 1) window coverage, 2) power generation efficiency, 3) canyon aspect ratio, and 4) façade orientation.
- The impact of BIPV window on T_{can} can enhance canyon thermal comfort, especially in winter.
- BIPV window can generate power and save cooling demand, but consume more lighting and heating energy, due to the smaller solar heat gain and visible transmittance.
- The energy benefit of BIPV window is more evident for buildings with higher solar access.
- We are applying the BEM-SLUCM into Weather Research and Forecasting (WRF) model to assess the impact of BIPV window in different cities under regional scale.

Acknowledgement

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