Predicting natural ventilation potential in idealised neighbourhoods

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This presentation participates in OSPP

EGU

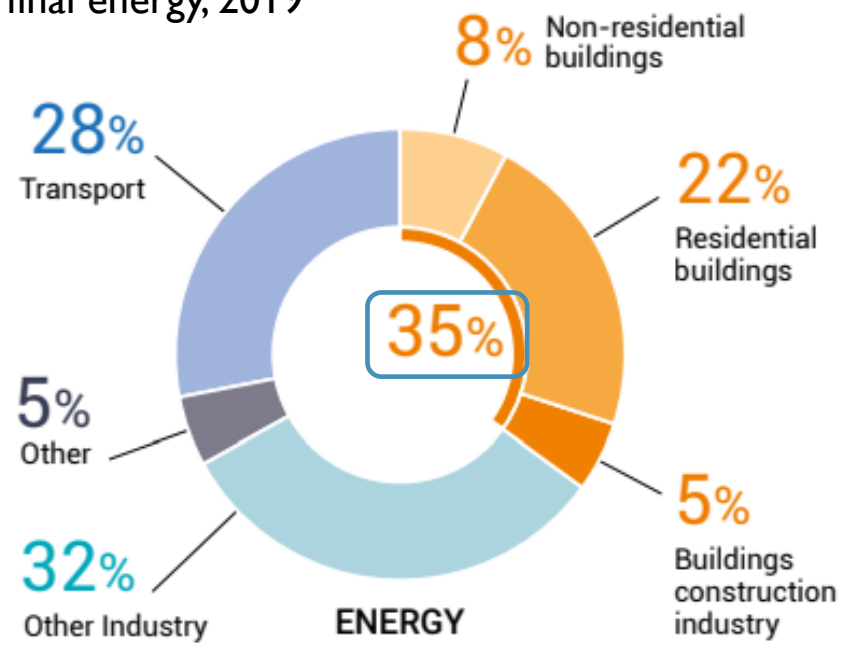
Outstanding Student & PhD candidate Presentation contest

University of Reading

EGU General Assembly 2022

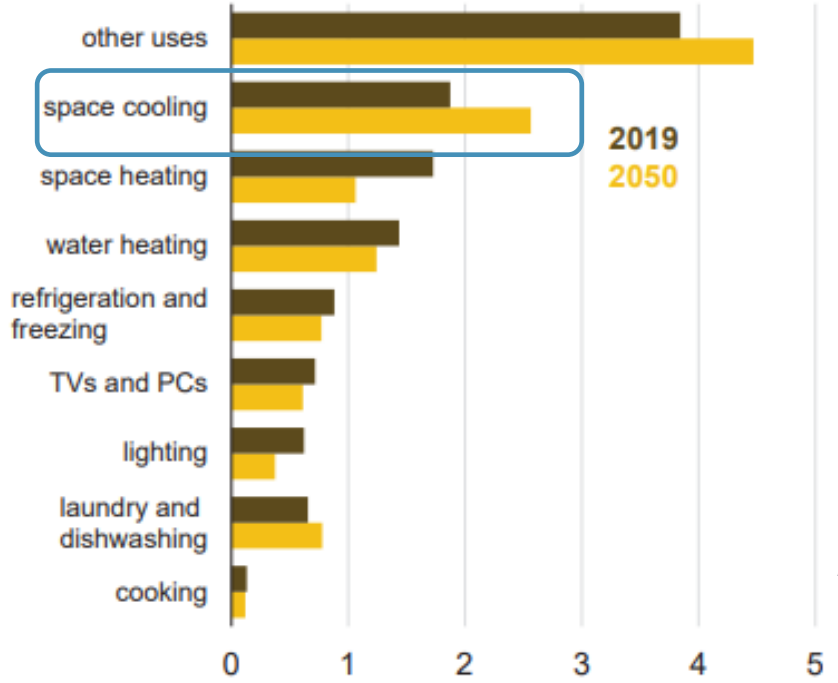
Background:
Why natural ventilation?

Global share of buildings and construction final energy, 2019



United Nations Environment Programme (2020)

Residential purchased electricity intensity (AEO2020 Reference case)
thousand kilowatthours per household



U.S. Energy Information Administration (2020)

- To improve indoor air quality and thermal comfort while reducing energy consumption

Background:
Natural ventilation potential assessment

Natural ventilation potential:
the possibility to ensure acceptable indoor thermal comfort and air quality by natural ventilation

Climate-based

- Analysing outdoor data
- Self-developed building physics model

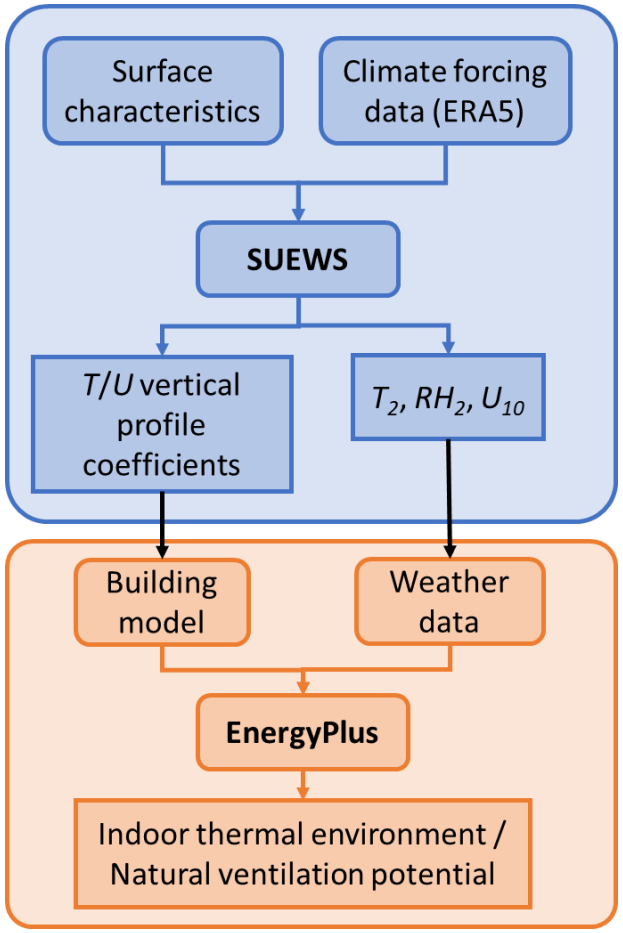
Design-based

- Building energy simulation
- Weather data from observation stations (rural only)
- Coupled with CFD

- Using rural weather data for urban building simulation cause biases
- Coupling building energy simulation tools to CFD models is computationally expensive
  - e.g. modelling 3 days takes ~ 1 week (Yang et al. 2012)

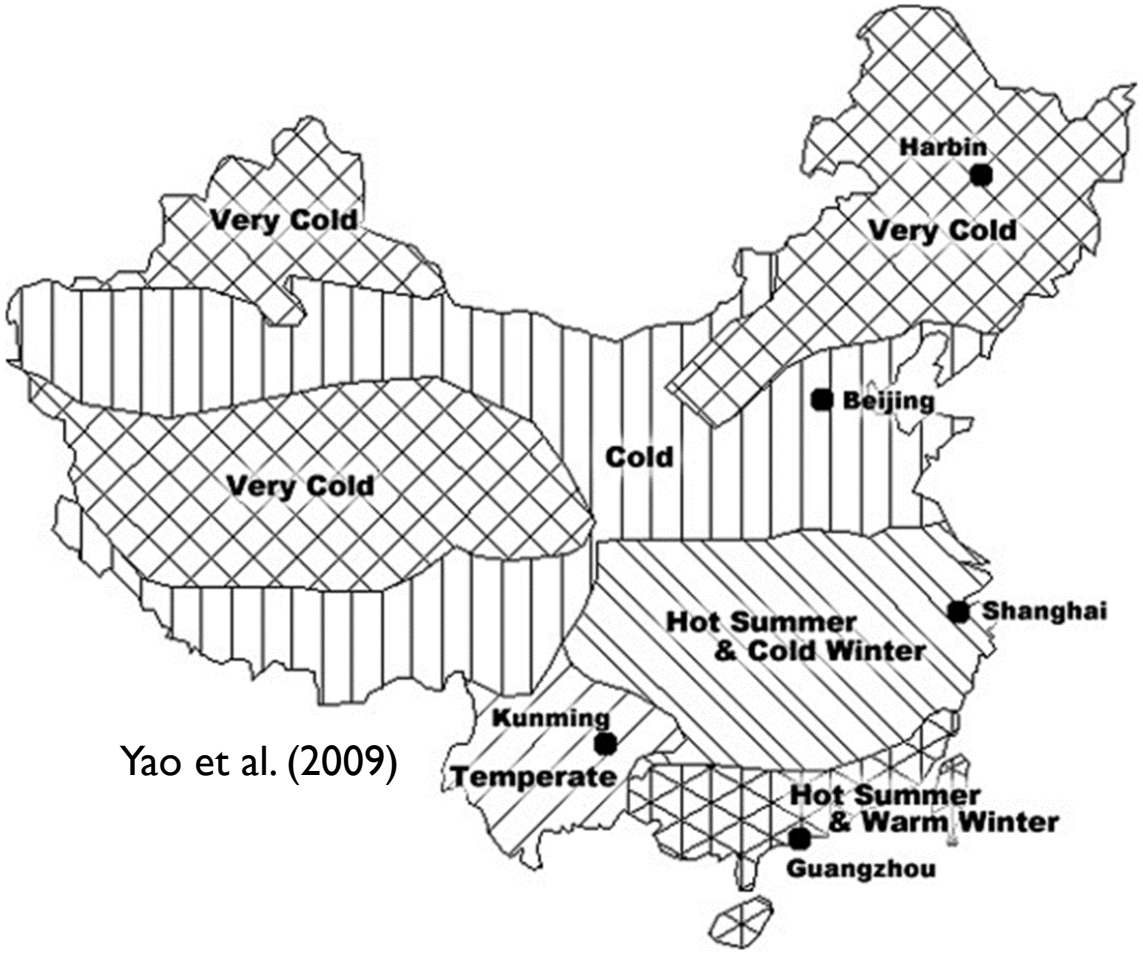
Method:
SUEWS-EnergyPlus

- Surface Urban Energy and Water Balance Scheme (SUEWS) (Jarvi et al. 2011, Ward et al. 2016)
  - Surface energy fluxes (Oke, 1987) and RSL diagnostics (Theeuwes et al., 2019)
- EnergyPlus (U.S. Department of Energy 2020)
  - Building heat & mass transfer and system simulations
- Well-evaluated, computationally cost-effective



Xie et al. (2022a)

A case study: Climate zones in China



Yao et al. (2009)

Very cold (VC): Harbin

Cold (C): Beijing

Cold winter hot summer (CWHS): Shanghai

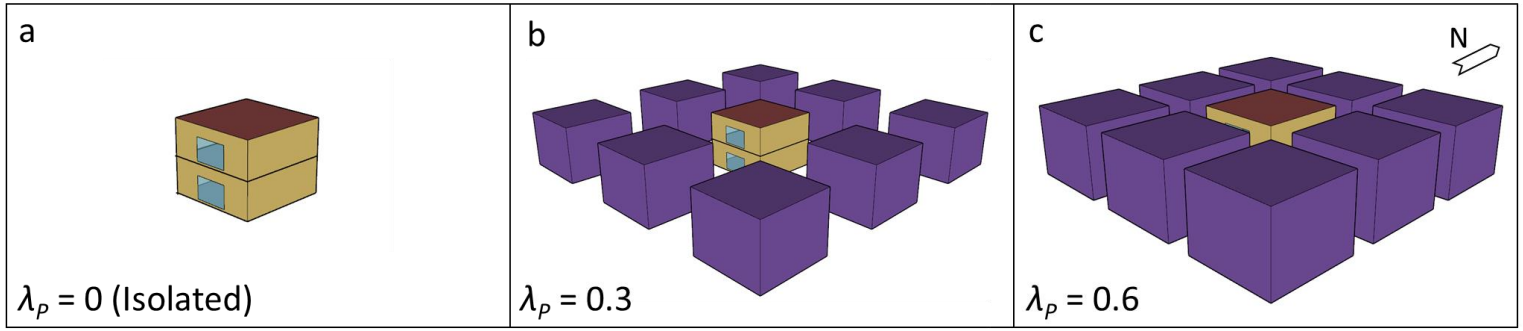
Temperate (T): Kunming

Warm winter hot summer (WWHS): Guangzhou

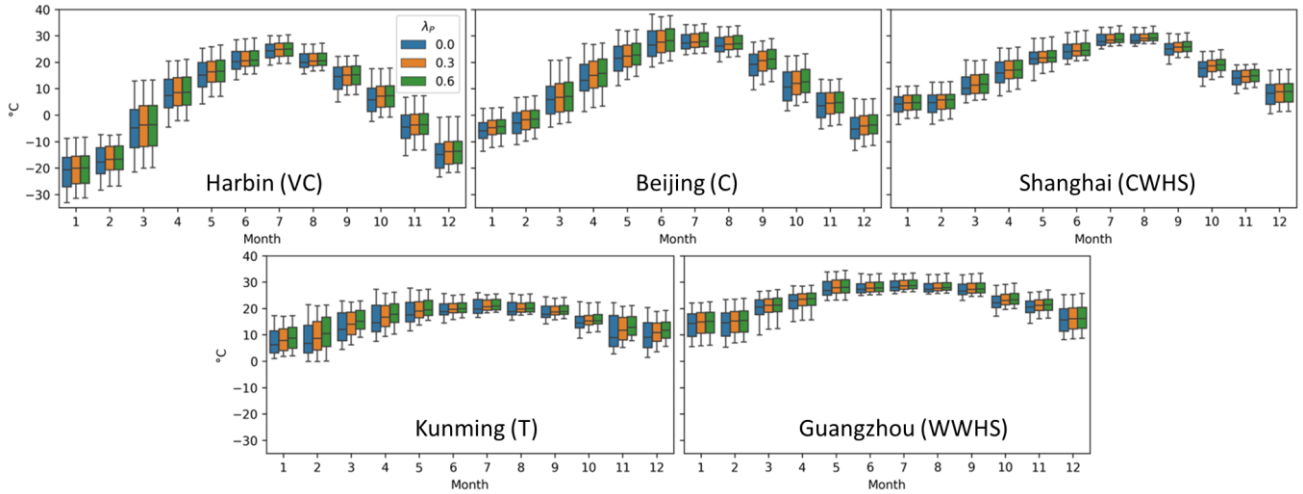
Photos source: Pixabay

Case study: Climate zones in China – different plan area fractions

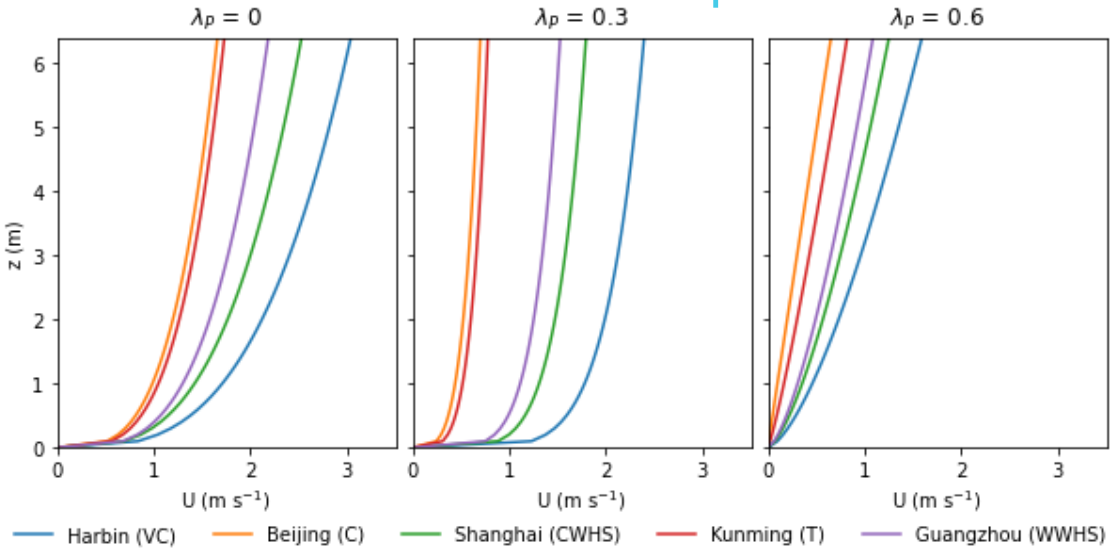
3 plan area fractions (λ_p)



Outdoor air temperature



Outdoor wind speed

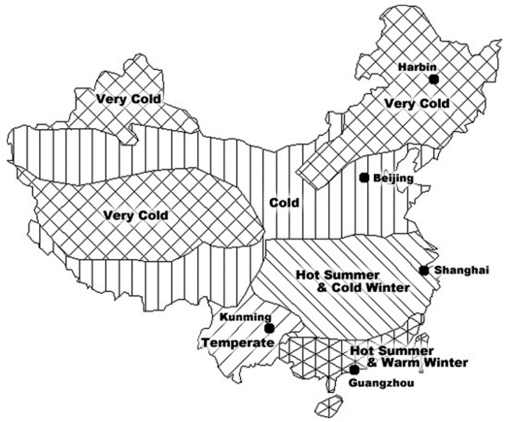


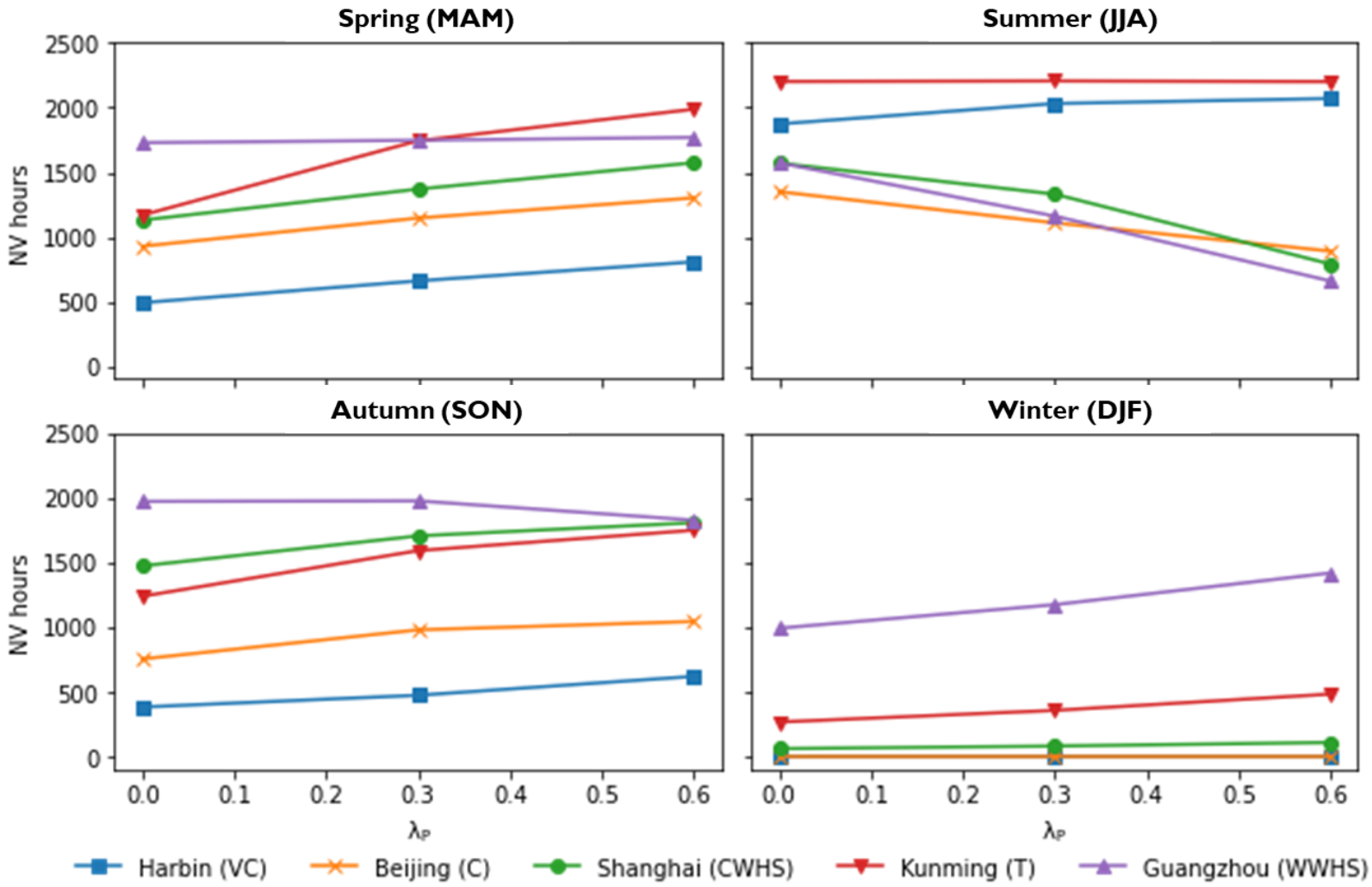
Xie et al. (2022a)

Climate zones in China: Different plan area fractions

Natural ventilation (NV) hours
number of hours in a naturally ventilated building when:

- Indoor air temperature: within the comfort range - adaptive thermal comfort
- Ventilation rate meets the minimum requirement for air quality - ASHRAE minimum ventilation rate





Xie et al. (2022a)

Final Comments

- Both climate and plan area fraction influence natural ventilation potential.
  - e.g. opposite summer/winter trends, etc.
- Practical approach to improve accuracy of EnergyPlus in simulating urban buildings (also see Xie et al., 2022b).

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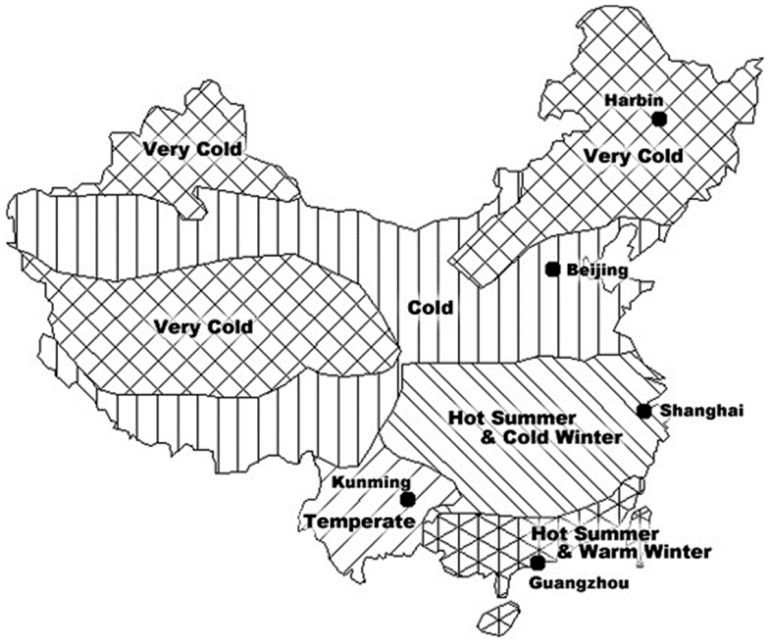
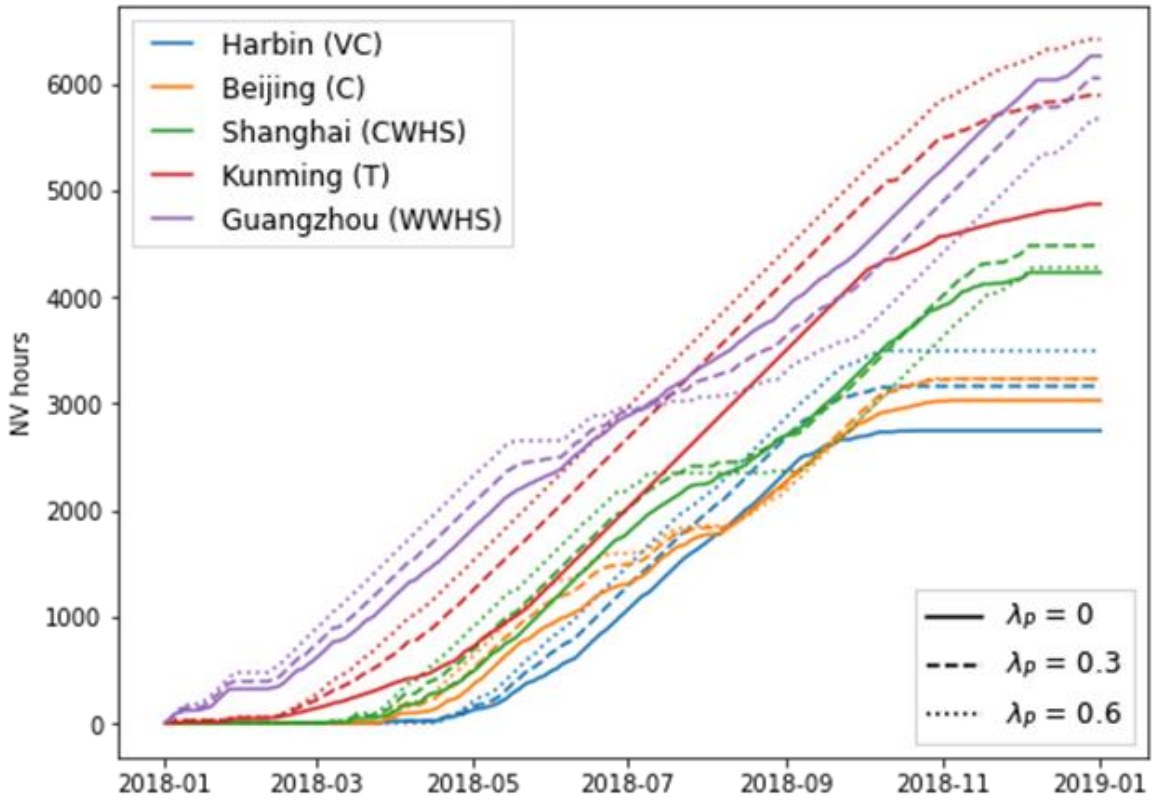
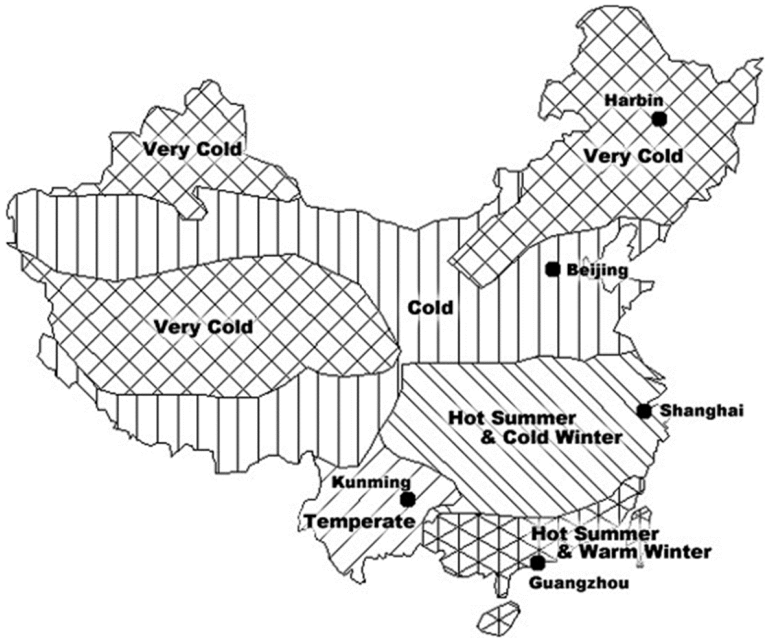
Appendix:
Annual cumulated NV hours

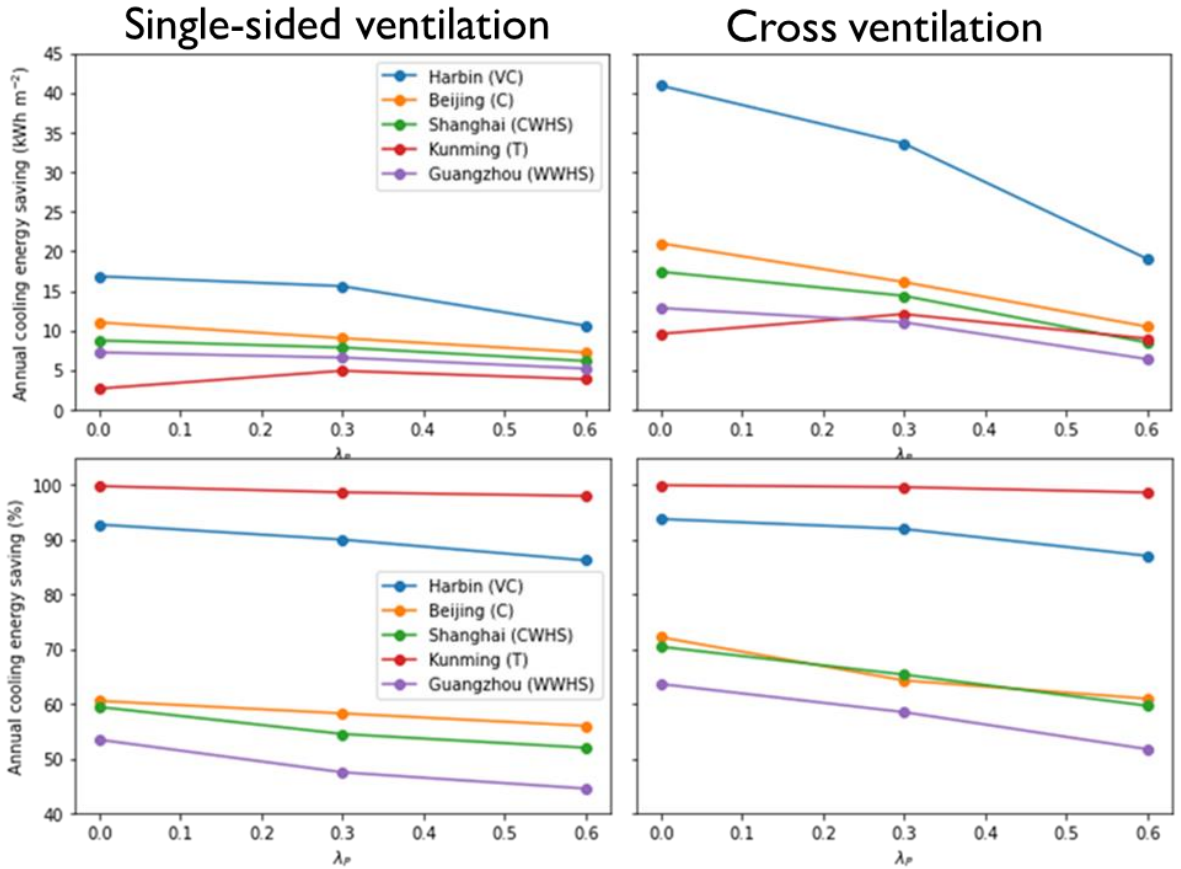




Xie et al. (2022a)

Appendix:
Cooling energy saving





Xie et al. (2022a)