# THE INTERACTION OF HVAC WITH GREEN ROOF AND ITS IMPACT ON URBAN HEAT ISLAND EFFECT

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## Introduction — Why bothered?

Urban surfaces capture more energy under solar radiation owing to the nature of the urban environment: the infrastructure and buildings made of concrete which has a low albedo ratio. Together with the intense human activity taking place in urban area, a temperature difference between the city and rural area is induced, known as the urban heat island effect. It is a topic that emerges as part of the climate change issue and people have been concerned and seeking for solutions to it. Green roof is one of the popular mitigating strategies. It is utilised by replacing conventional roof structure with vegetation and plants that have evapotranspiration and give rise to latent heat flux. The efficiency of green roof has been evaluated by precedent study and the result is not satisfactory. However anthropogenic heating sources were omitted and building dynamics was not modelled in previous studies. Therefore this project aims to investigate the effect of the inclusion of building HVAC and other anthropogenic heating sources on green roof efficiency and how it affects the urban heat island effect.

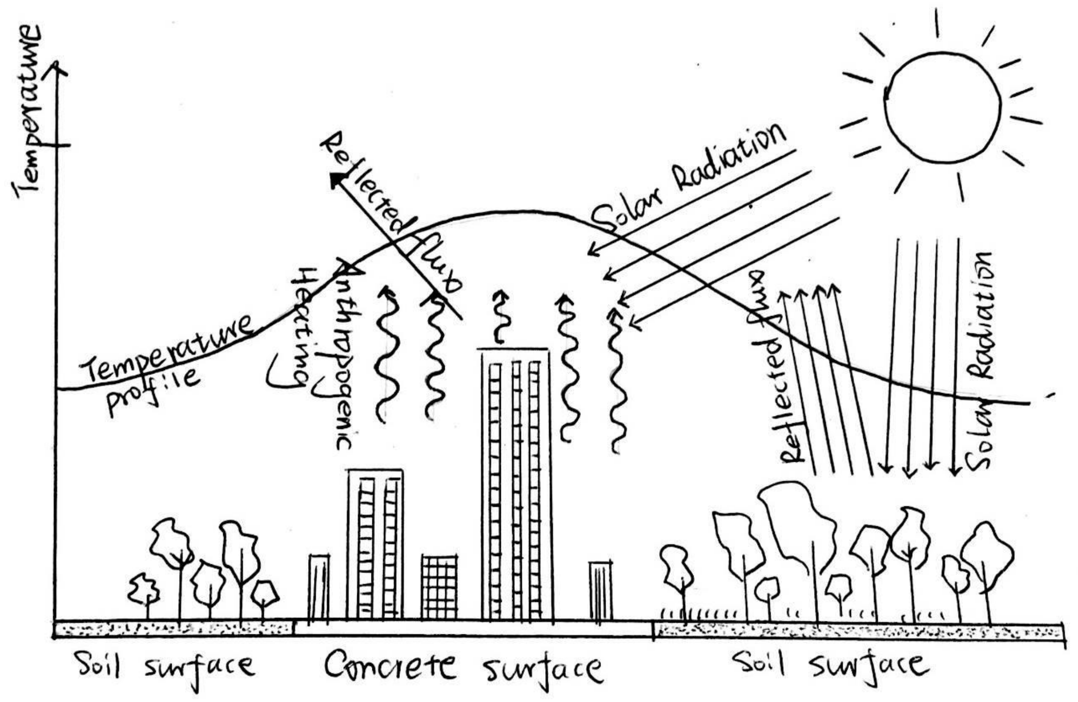


Figure 1: A schematic illustration of urban heat island effect.

## The Modified Town Energy Budget Model — The state of art

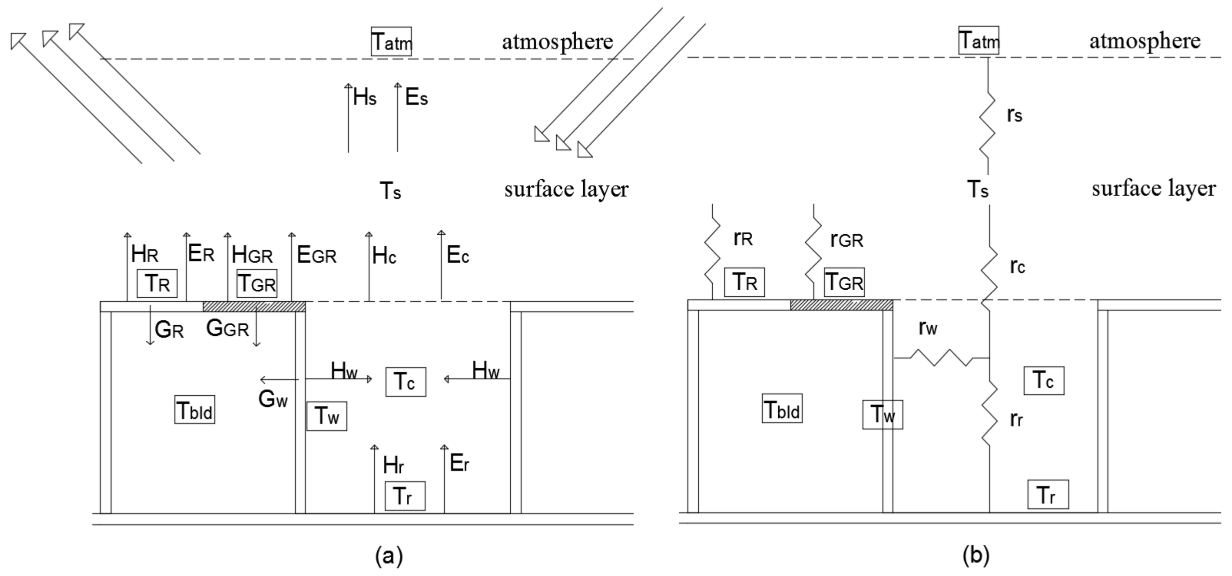


Figure 2: The energy fluxes (a) and aerodynamics resistances (b) of the MTEB model

$$c_* d_* \frac{dT_*}{dt} = S_* + L_* - H_* - E_* - G_* \quad (1)$$

$$c_s d_s \frac{dT_s}{dt} = (a_R H_R + a_c H_c + a_G H_{GR} - H_s) \quad (2)$$

$$T_c = \frac{\frac{T_r}{r_r} + \frac{T_w}{r_w}\frac{2h}{w} + \frac{T_s}{r_c}}{\frac{1}{r_c} + \frac{1}{r_r} + \frac{1}{r_w}\frac{2h}{w}} \quad (3)$$

$$H_* = \frac{c_p \rho_a (T_x - T_*)}{r_*} \quad (4)$$

$$E_* = \frac{L_v \rho_a \delta_* (q_x - q_*)}{r_*} \quad (5)$$

$$G_* = \lambda_* \frac{(T_* - T_{bld})}{d_*} \quad (6)$$

The modified town energy model is an urban energy balance model developed by Suter et al. (2016). In the MTEB, a city is represented by generalized building and street canyon, which is illustrated in Figure 2. The energy budget of the roof, green roof, wall and road surfaces are given in Equation (1) where the * denotes different surfaces respectively. The sensible heat flux (H), latent heat flux (E) and conduction heat flux (G) are given in Equations (4 – 6). By solving these energy budget equations, the time series for the temperature evolutions can be found out.

## Inclusion of HVAC in MTEB

The energy balance through the boundaries of the building is given in Figure 4. The HVAC is modelled as a sink term which extracts all excess energy fluxes from conduction and source term to keep the room at a constant temperature. The energy budget for the building is given in Equation (7) from which the expression for the HVAC heat flux can be obtained. The temperature equations for the street canyon and surface layer are modified by including anthropogenic heating sources accordingly. The parameter $a_v$ denotes the fraction of HVAC heat flux that is being expelled through the roof to the surface layer.

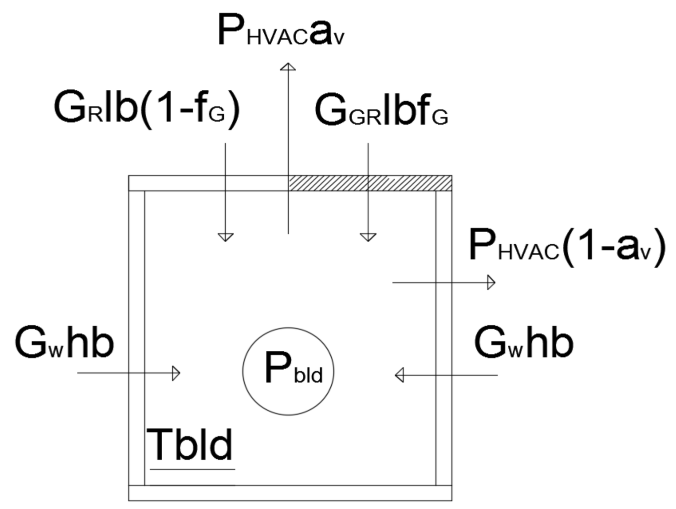


Figure 3: Illustration of the building control volume

$$\rho C_p \frac{dT_{ibld}}{dt} blh = G_w 2hb + G_R lb(1 - f_G) + G_{GR} lbf_G + P_{bld} - P_{HVAC} \quad (7)$$

$$T_c = \frac{\frac{T_r}{r_r} + \frac{T_w}{r_w}\frac{2h}{w} + \frac{T_s}{r_c} + \frac{P_{HVAC}(1-a_v)}{\rho c_p w} + \frac{H_{trf}}{\rho c_p (1 - a_{bld})}}{\frac{1}{r_c} + \frac{1}{r_r} + \frac{1}{r_w}\frac{2h}{w}} \quad (8)$$

$$c_s d_s \frac{dT_s}{dt} = H_R a_R + H_{GR} a_{GR} + H_c a_c - H_s + \frac{P_{HVAC} a_v}{l + w} + H_{ind} \quad (9)$$

## Results - Discussions

Inclusion of HVAC increases the UHI effect by 1.24 – 9.45 K depending on $a_v$. Green roof reduces the HVAC heat flux by roughly 15% and its efficiency in reducing outdoor temperature is improved by inclusion of HVAC. The HVAC heat flux also reduces when it is discharged into the surface layer instead of the street canyon. For every £1 spent on green roof there is 10 times as much return through energy saving in HVAC emission. HVAC emission increases as urban temperature increases.

## Results - Diagrams

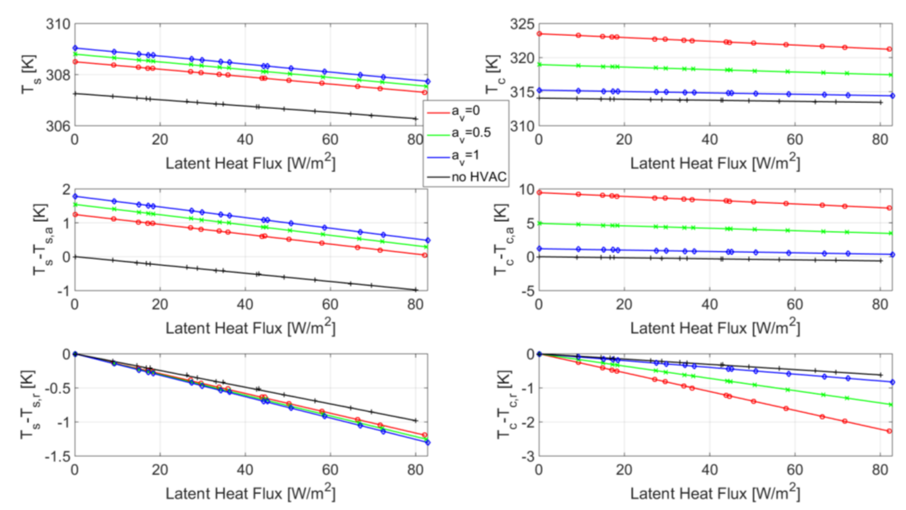

Figure 4: The simulation results for the relationship between green roof and outdoor temperatures in different interpreting ways.

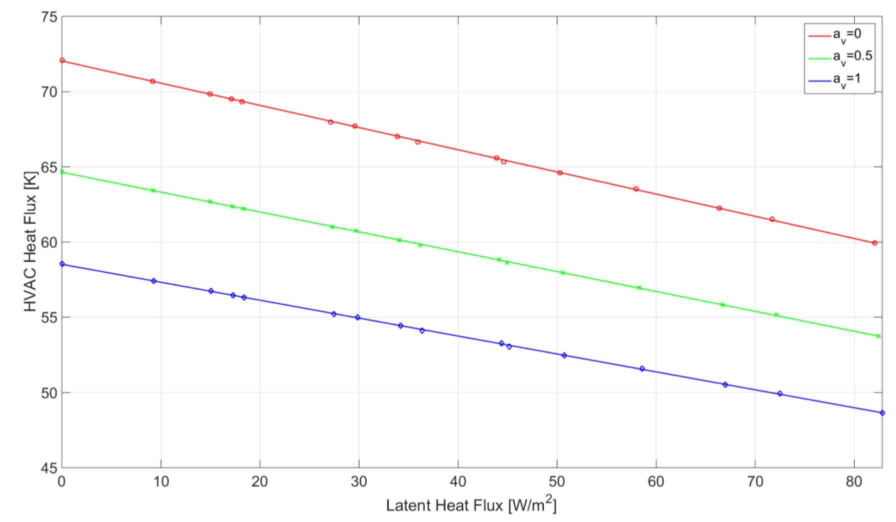


Figure 5: The relationship between green roof and HVAC

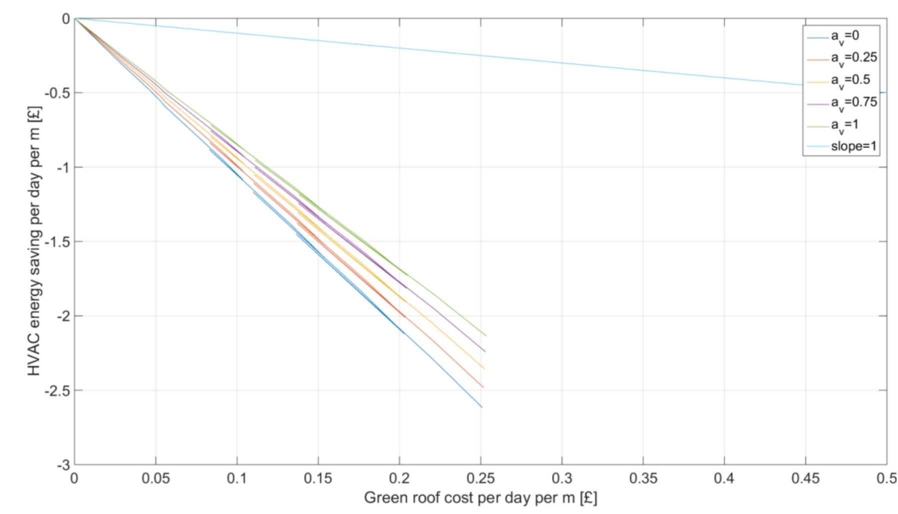


Figure 6: The relationship between green roof cost and HVAC energy saving potential

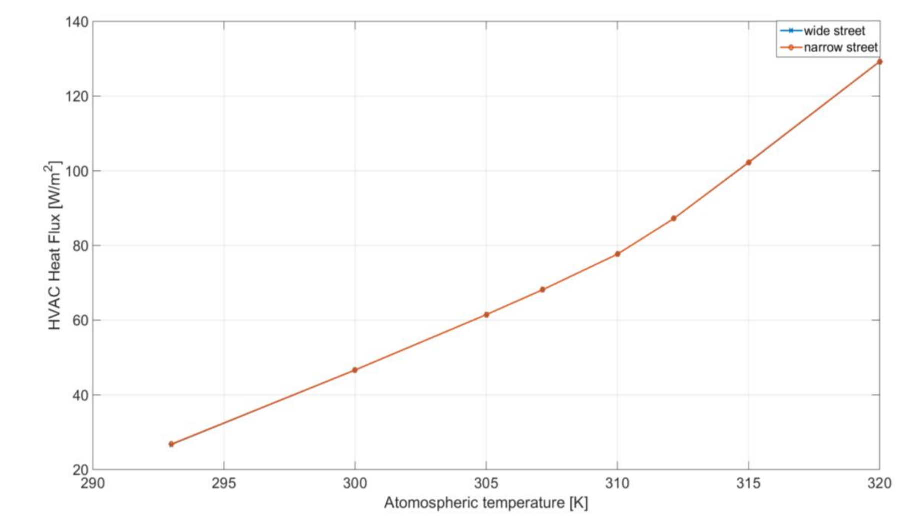


Figure 7: The relationship between atmospheric temperature and HVAC heat flux

## CONCLUSIONS

- The cooling potential of green roof is improved when HVAC is present.
- Discharging HVAC heat to the surface layer instead of street canyon can relieve its impact on UHI effect.
- Green roof reduces HVAC emission and investment in green roof is cost-effective with respect to energy saving in HVAC.
- Cities in hotter regions should give more consideration to green roof for higher efficiency.
- Figure 8 gives a schematic illustration to the interaction between HVAC, green roof and UHI

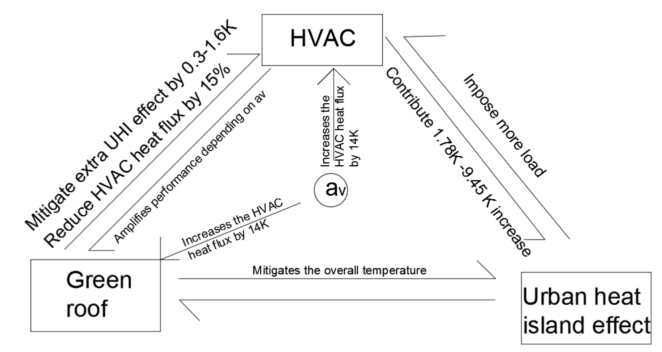


Figure 8: A schematic overview of the interaction between HVAC, green roof and UHI effect.


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## REFERENCES


Suter, I., Maksimovic, C. & van Reeuwijk, M (2016) A city-scale estimate for the cooling potential of green roofs. *Environ. Res. Lett.* [In press] [Accessed: 16th March 2016]