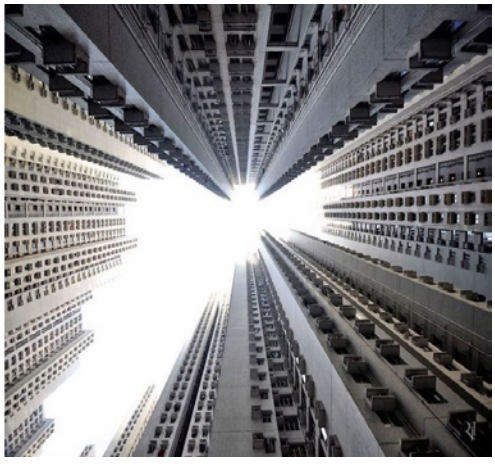
# D. CHAD McKEE

# CLIMATE-RESPONSIVE HIGH-RISE HOUSING



DESIGN FOLIO
FACULTY OF
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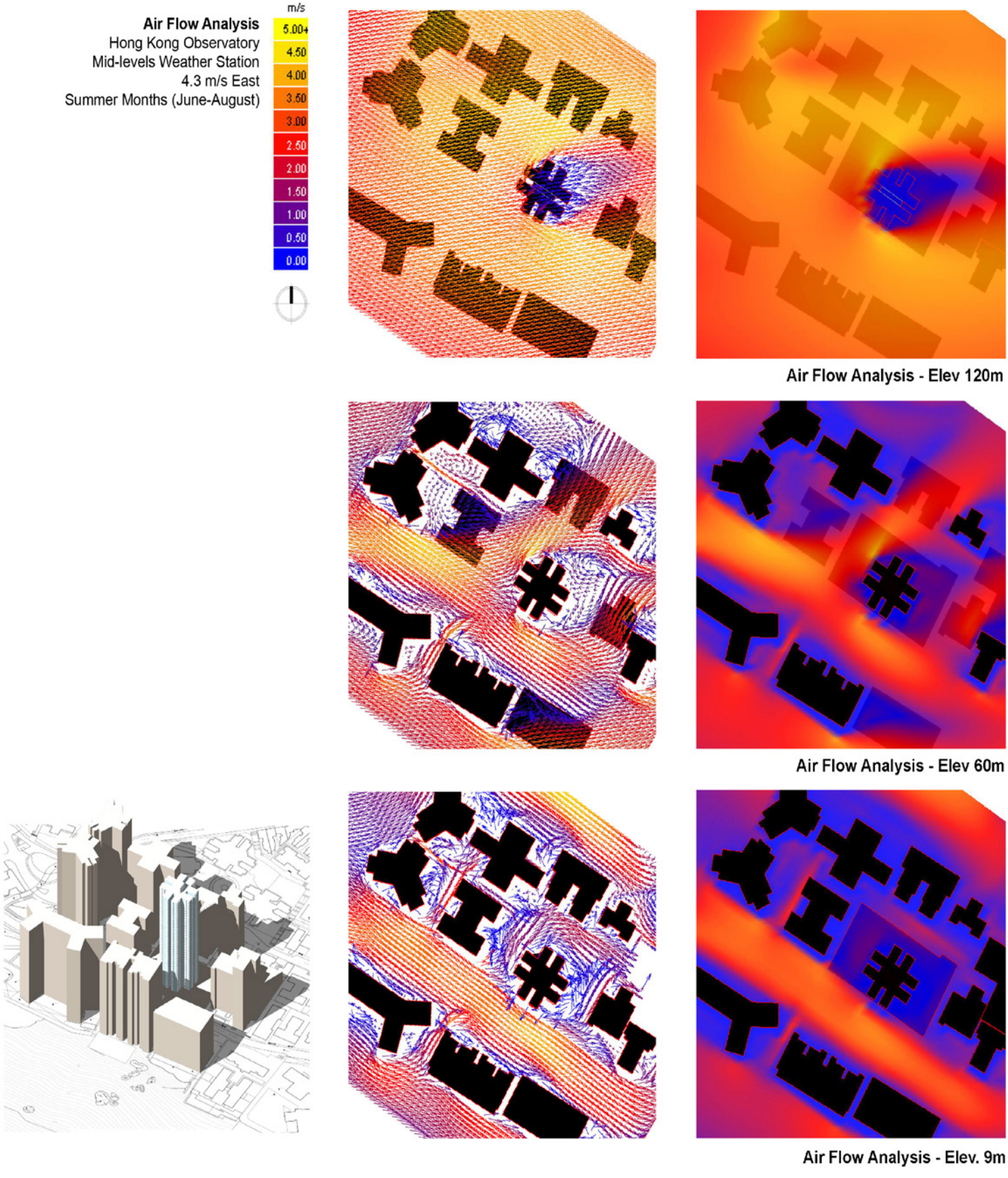
UNIVERSITY OF
HONG KONG

# Content




[1] Air flow simulation analysis of the cruciform high-rise typology located in residential density zone 2. Results shown at 9m, 60m, and 120m elevation above street level (McKee, 2016)

## Project Details

### Author
D. Chad McKee

### Title
Climate-Responsive High-rise Housing:
Adaptive Strategies for the Vertical Climatology of Hong Kong

### Output
Exhibit

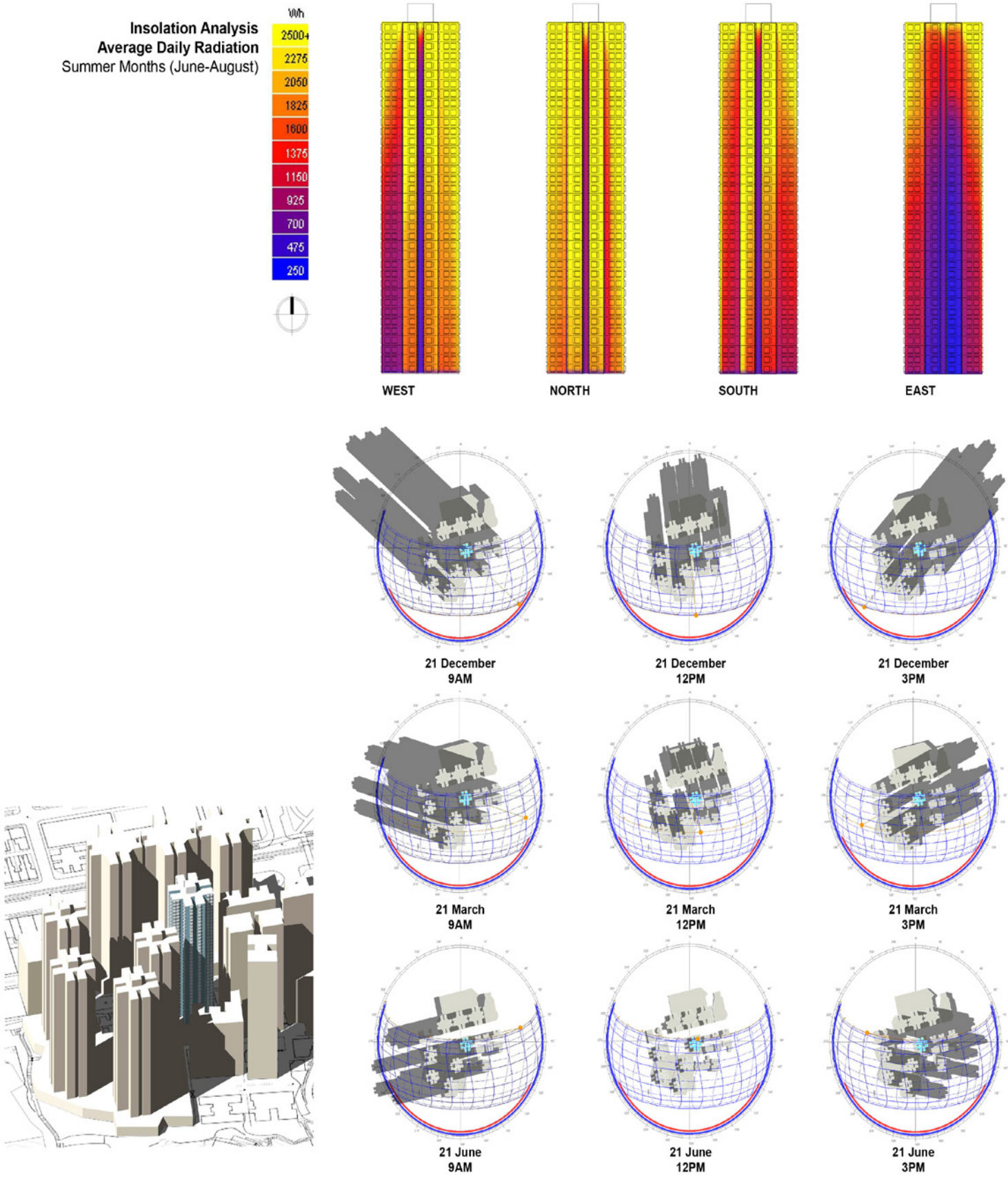
### Function
Sustainable Environmental Design Strategies and Policy Research for High-rise Residential Bldgs.

### Location
Hong Kong, S.A.R. China

### Exhibition Title
The Liveability of Design

### Venue
Hong Kong Central Government Complex

### Dates of installation
September-November 2017




[2] Insolation analysis of all vertical surfaces and annual sun path/shadow diagrams of the cruciform high-rise typology located in residential density zone 1 (McKee, 2016)

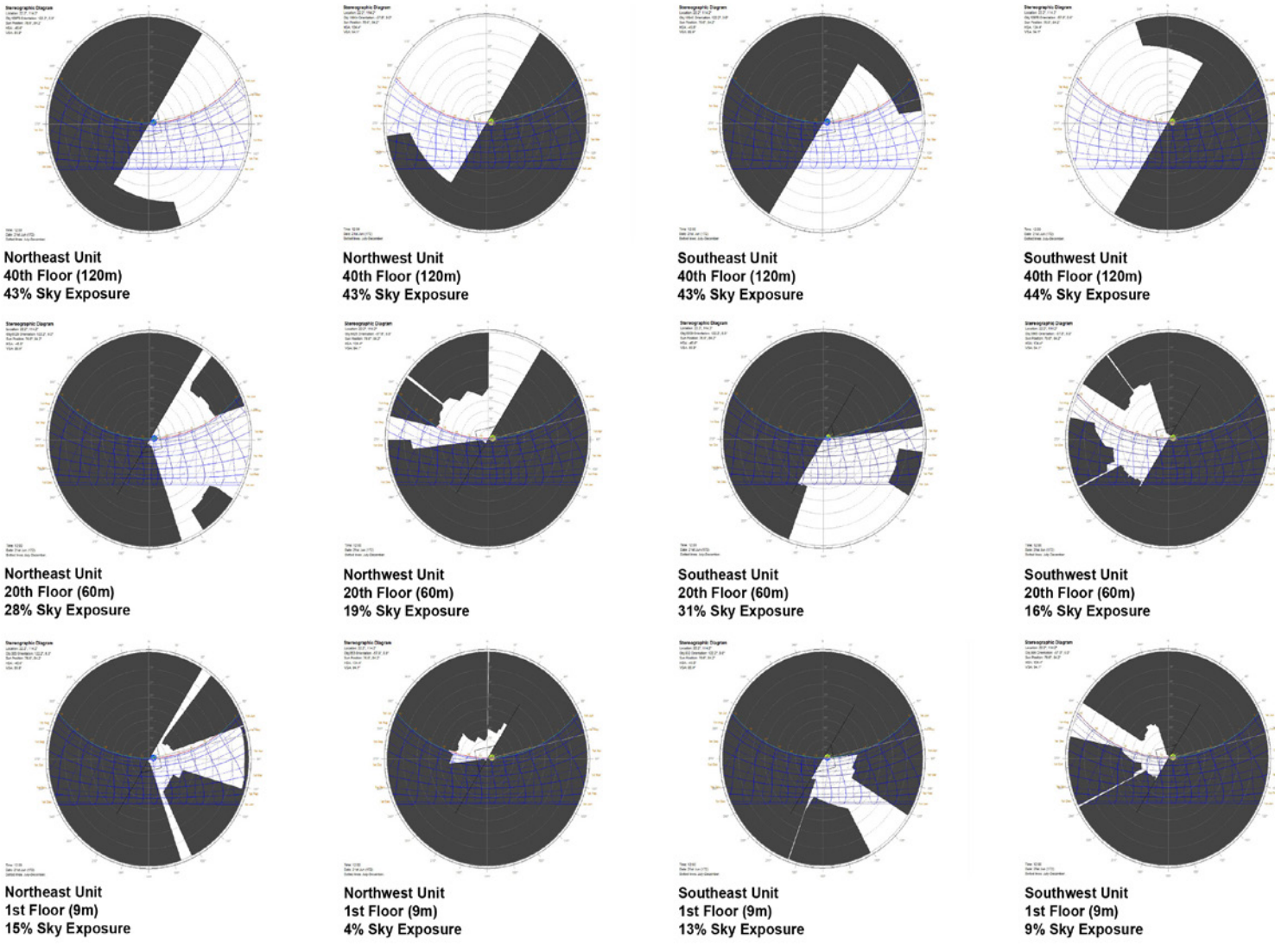
## Summary of the Work and its Significance, Originality, and Rigor

The Climate-Responsive High-rise Housing research project explores sustainable environmental design strategies and policy recommendations for high-rise residential buildings in high-density, warm and humid urban settings. Drawing from on-site fieldwork, occupant interviews and environmental analytic simulations of five existing high-rise residential buildings in Hong Kong – each representing a unique high-rise typology - this research project quantifies and makes visible the unseen environmental forces affecting occupant thermal comfort and energy-use, and questions how the host architecture and surrounding urban morphology

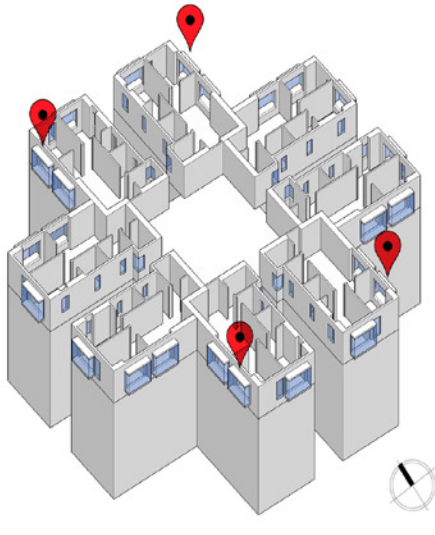
play a role in shaping the thermal environments both within and outside of tall buildings. Conventional knowledge about sustainable environmental design is often undermined or invalidated by the human activities and variable levels of obstruction and exposure found in high-density urban settings. Therefore the design and research agenda of this project explores a new high-density urban calibration of sustainable environmental design strategies for high-rise residential buildings by quantifying and responding to the daily, seasonal, and sectional variations found in Hong Kong's high-density vertical microclimates.

The Climate-Responsive High-rise Housing research project was invited for presentation at the Development Bureau of the Hong Kong Central Government's

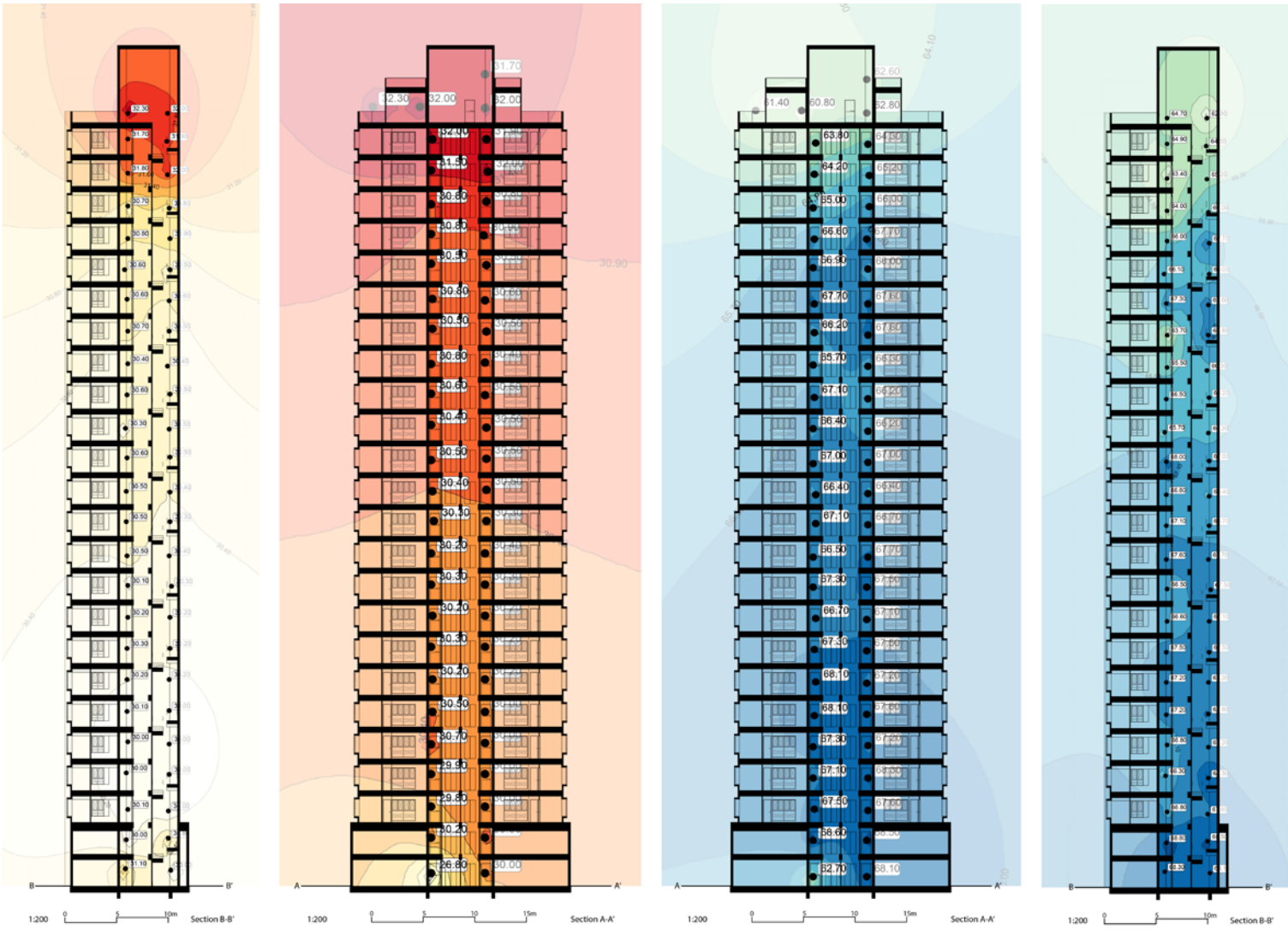
‘Liveability by Design’ exhibition, and was subsequently peer-reviewed by the Hong Kong Arts Development Council and the Hong Kong Institute of Architects and selected for exhibition in the Hong Kong pavilion at the 2018 Venice Biennale International Architecture Exhibition in Venice, Italy. Knowledge gained from this research project forms the basis of a forthcoming book to be published by Routledge in winter 2020.




**Stereographic Sky-Exposure Diagrams**
Location: 22.2°, 114.2°
Sun Position: 76.6°, 84.2°
HSA: 178.9°
VSA: 95.8°



[3] Stereographic sky-exposure diagrams of the cruciform high-rise typology in residential density zone 1. Results shown at elev. 9m, 60m, and 120m above street level. (McKee, 2016)




[4] Fieldwork data collection for air temperature and humidity values found in the trident high-rise typology located in residential density zone 2. Results shown at every floor. (McKee, Hui, Yang, 2017)

## Originality

What do existing high-rise buildings in high-density urban settings tell us, and what can we say about sustainable environmental design in return (Yannis, 2009)? This is the key question that underpins the Climate-Responsive High-rise Housing research project. Hong Kong's high-density urban morphology and high-rise buildings form the test ground for evaluating how basic principles and methods of sustainable environmental design should be calibrated for high-density urban settings in warm humid climates. Key to this process is to question the inherent planar symmetry and vertical repetition of high-rise buildings found in Hong Kong by harmonizing the needs of people with the vertical climatology of site.

## Research Questions

- In what ways are air movement, daylight, solar orientation and exposure affected by variations of urban density and form?
- How should we measure, index and visualize these environmental parameters? How should we interpret these findings into an architectural response for high-rise buildings?
- In what ways should high-rise building typologies respond to environmental variations according to plan and section?
- What role can operable or adjustable elements of building enclosure play toward mediating the high-rise building's environmental properties? And what are the subsequent impacts on plan depth, room geometry, the relationships between spaces in plan and section, the admission and control of solar radiation, daylight, airflow, and the adaptive mechanisms for thermal and visual comfort?
- How are the interior and exterior spaces of the high-rise building to be used? And how might the use of space vary within and between rooms, according to time, location, and climatic conditions?
- In what ways does the presence and activities of occupants create differing environmental profiles for the high-rise building and its surrounding?

## Morning Survey

(11th Sep, 2015, Tuesday 9:45 - 12:15)

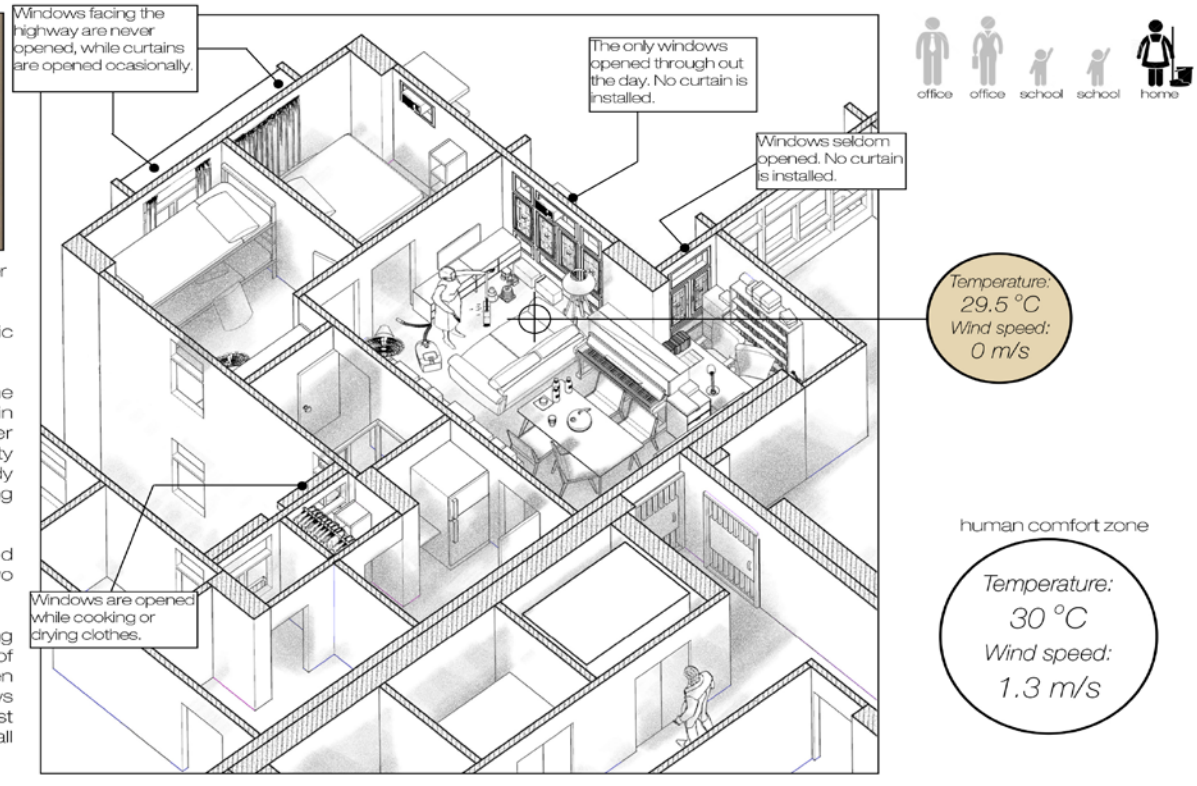
Interviewee: maid of the flat owner
Interviewer: Felice Chap

Q: What do you find problematic when living in this flat?

A: It's very hot and humid in the summer. We ususally use fan in the morning and air conditioner at night in order to save electricity bills. Even though I have already opened the windows at the living room, it doesn't help much.

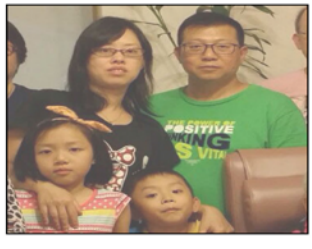
Q: Why the windows and curtains are all closed at the two bedrooms?

A: These two bedrooms are facing the highway that brings in lots of dust and heat, so we never open these windows, but only windows at the living room. However, dust still get in and I have to sweep all the time.




## Night Survey

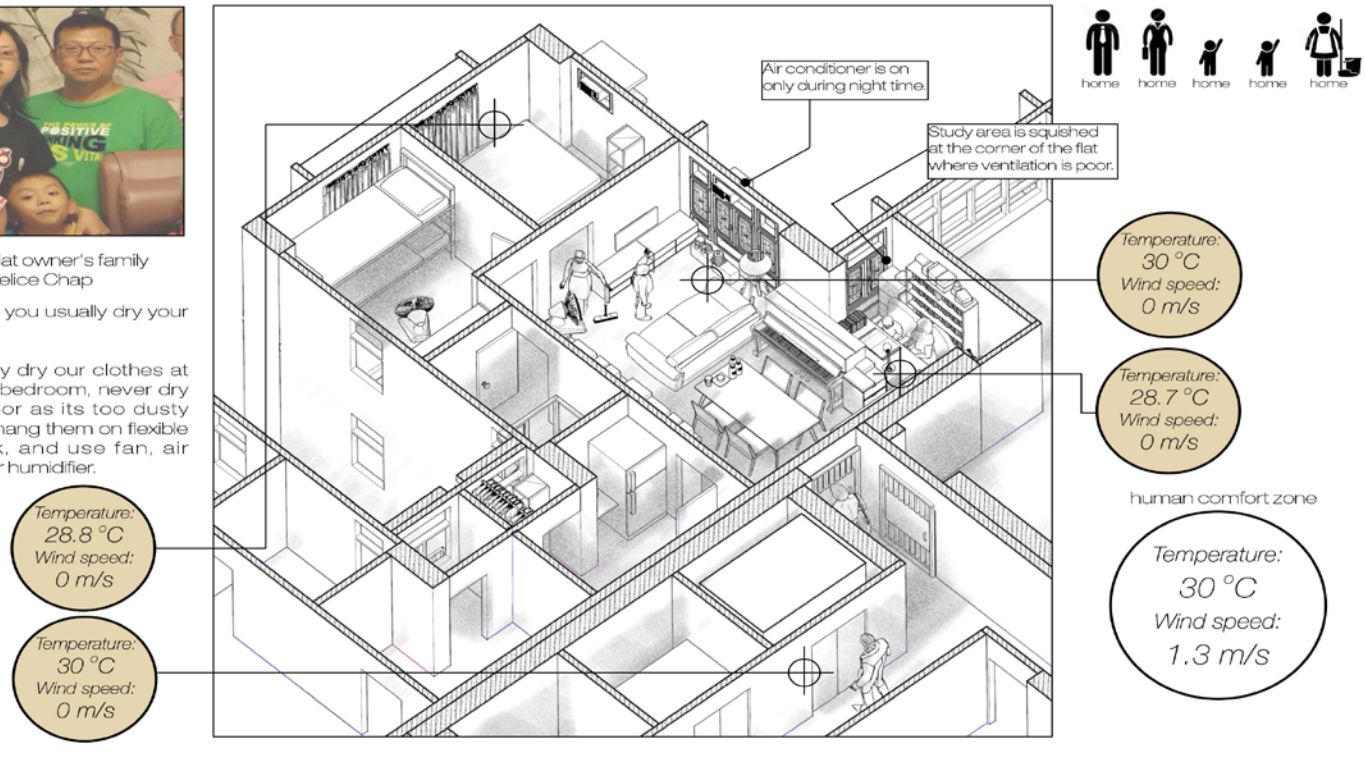
(11th Sep, 2015, Tuesday 18:00 - 19:00)



Interviewee: flat owner's family
Interviewer: Felice Chap

Q: Where do you usually dry your clothes?

A: We usually dry our clothes at kitchen and bedroom, never dry them outdoor as its too dusty outside. We hang them on flexible drying rack, and use fan, air conditioner or humidifier.

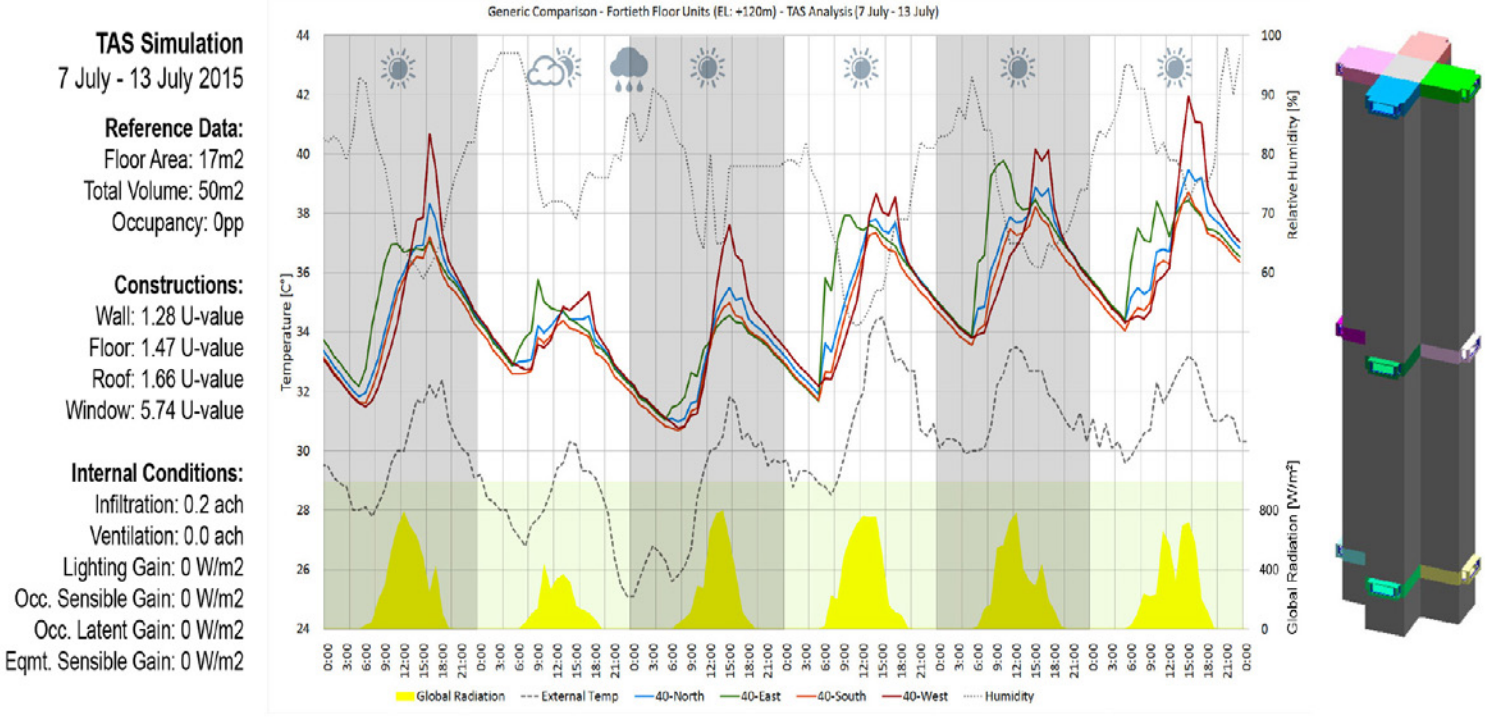



[5] Fieldwork occupant interviews at the cruciform high-rise typology located in residential density zone 2. (McKee, Suen, Chap, 2016)

## Rigor

The Climate-Responsive High-rise Housing research project initially analyzed, by means of on-site fieldwork and dynamic thermal modelling, five unique housing typologies (slab-block, cruciform, trident, pencil tower, and ‘tong lau’ tenement building) in Hong Kong. Spot measurements and data logger readings for air & surface temperatures, humidity, wind speeds, daylight and solar exposure were collected according to orientation and elevation (ground, mid-level, and penthouse elevations) over the course of one typical summer week to clearly define the specific environmental parameters affecting the vertical climatology of each site and to document how the building form, organization, and support systems

respond accordingly. Site interviews with inhabitants were conducted to establish working knowledge of occupant behavior within each site. This combination of on-site empirical studies with dynamic thermal simulations provided the means for formulating questions and testing environmental parameters for high-density high-rise housing, as well as supporting future design research and its generative processes.




[6] Thermal analysis computer model and simulation results for cruciform high-rise typology located in residential density zone 1. Results shown at elev. 9m, 60m, and 120m above street level, according to North, South, East , West (McKee, 2016)

## Significance

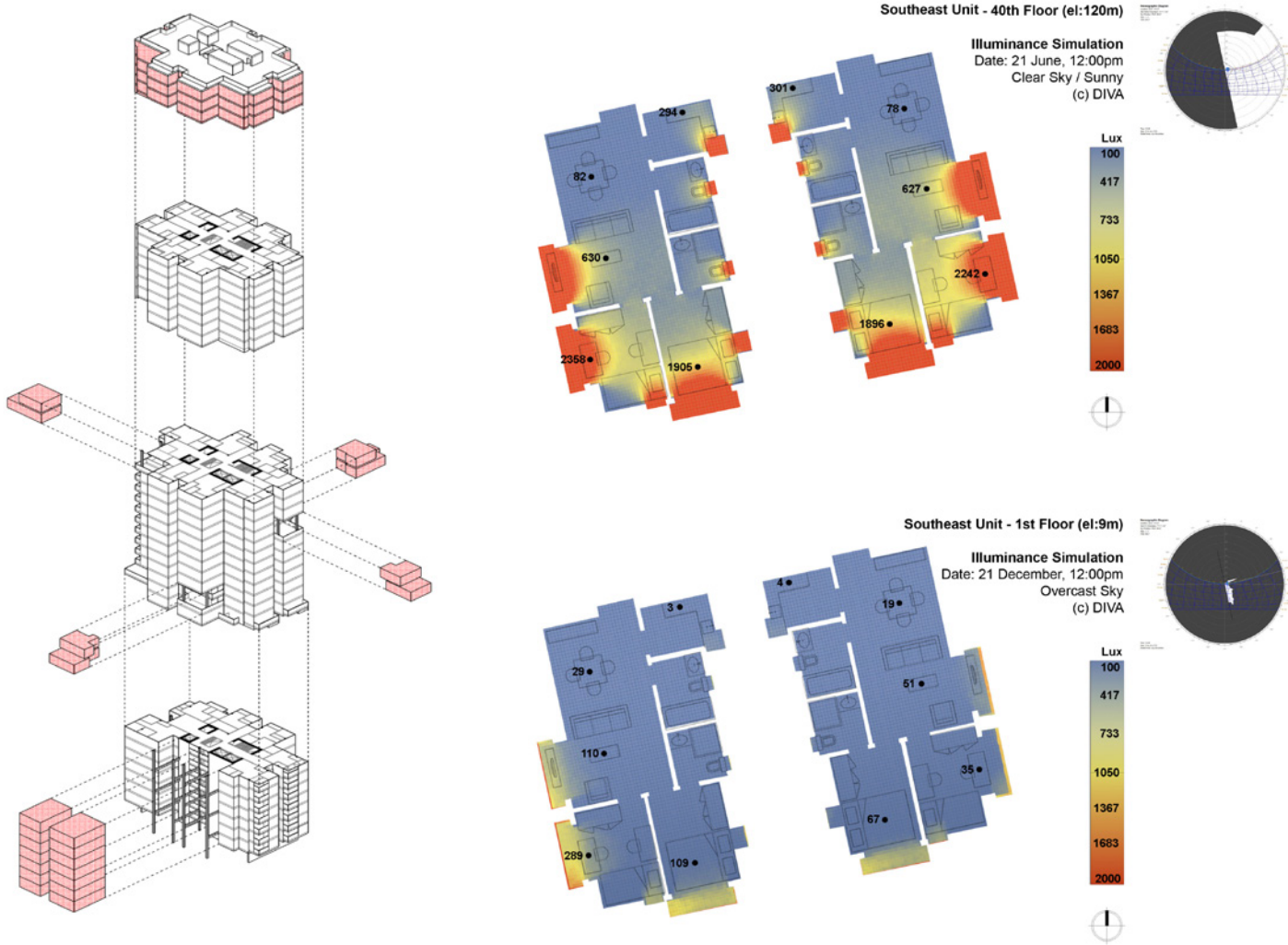
Due to the competing pressures of climate change and population growth, Hong Kong's urban fabric, like much of the world's cities, is growing warmer and more compact, and thus more dependent upon mechanical systems and the import of energy to achieve thermal comfort. This urban phenomena has altered the city's subtropical climate and produced a complex array of urban heat islands and layered micro-climates squeezed between tall buildings. Urban heat is intensified by the city's anthropogenic activities, building operations, and dense urban morphology, and stratified in section from the street level to the rooftops. And yet, the vast majority of Hong Kong's high-rise residential buildings are symmetrical in plan,

repetitive in section & elevation, and wholly dependent upon mechanical systems for thermal comfort - thus ignoring the environmental potentials and variations of the surrounding urban microclimates. The Climate-Responsive High-rise Housing research project seeks to provide alternatives to the energy-dependent high-rise architecture and “brute force” engineering that are the norm for Hong Kong architects today by providing new knowledge on what sustainable environmental design means for high-density, subtropical environments, and how the architecture of high-rise residential buildings can express these ideas, thus “reclaiming and enhancing architecture’s traditional role as a tool of environmental design” (Yannas, 2009).

## Dissemination and Evidence of Peer Review

The Climate-Responsive High-rise Housing research project was invited for exhibition at the Hong Kong Central Government Headquarters by the Hong Kong Development Bureau Secretary. This work was subsequently peer-reviewed by the Hong Kong Arts Development Council and the Hong Kong Institute of Architects and selected for exhibition (in-part) in the Hong Kong pavilion at the 2018 Venice Biennale International Architecture Exhibition. This work has also been widely shared through invited presentations at the Passive Low Energy Architecture (PLEA) conferences in Hong Kong (2018), Edinburgh (2017), and Los Angeles (2016) , and additionally peer-reviewed

at the Sustainable Environmental Design workshops at Tsinghua University (2016) and The Architectural Association (2015). Knowledge gained from this research project forms the basis of a forthcoming book to be published by Routledge in winter 2020.




[7] Interior illuminance simulation of cruciform high-rise typology located in residential density zone 2. Results shown for elev. 9m and 120m above street level. (McKee, 2016)

Related publications
by the designer:

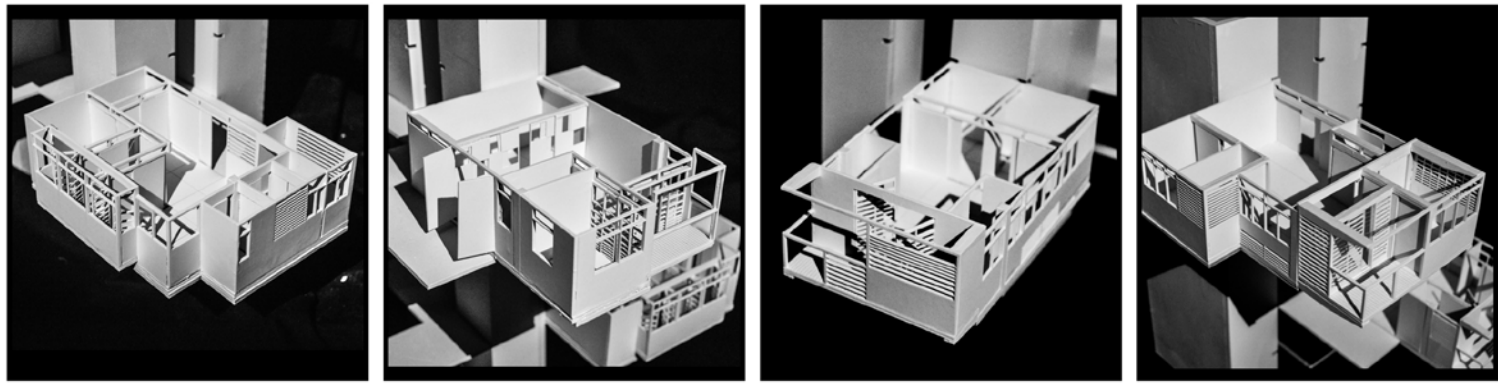
McKee, D., S. Yannas (2017). *High-rise Residential Building Enclosure: Environmental Considerations for Balconies in Hong Kong*. Design to Thrive, PLEA 2017, Edinburgh.

McKee, D., S. Yannas (2016). *High-rise Residential Building Enclosure: Adaptive Strategies for Hong Kong's Projecting Bay Windows*. Cities, Buildings, and People: Towards Regenerative Environments, PLEA 2016, Los Angeles.

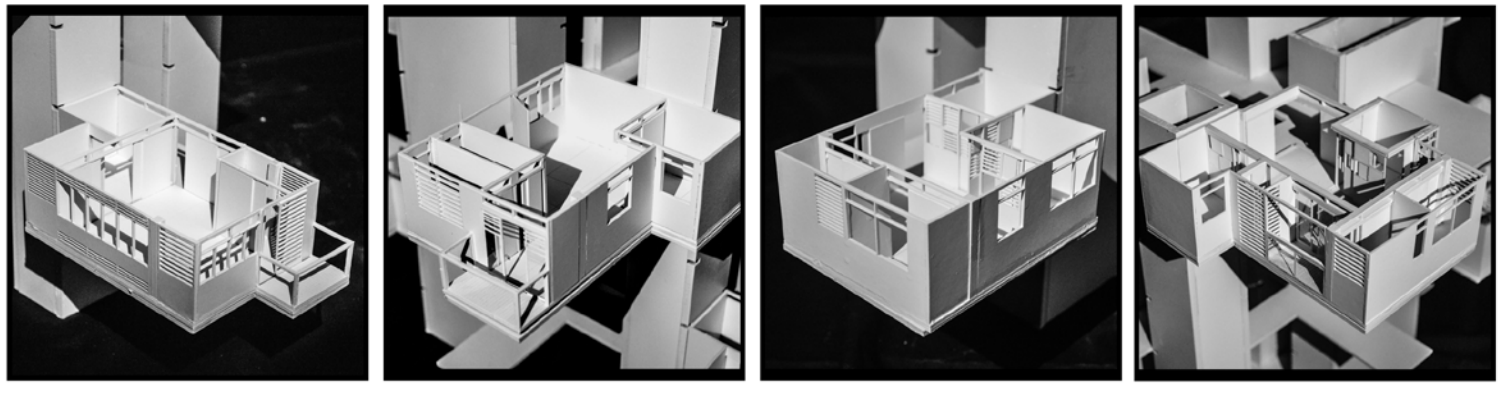
Briz, J., K. Cheung, D. McKee, S. Hui (2015). *Challenges to Improving Green Urban Environments by Urban Agriculture: The Cases of Hong Kong and Madrid*. Green Cities in the World. 2nd Edition, pp311-330, Editorial Agricola Española S.A., Madrid.

McKee, D. (2015). *Adaptive Design Strategies for High-rise Residential Buildings in Hong Kong*. MSc Dissertation. Architectural Association Graduate School, London.

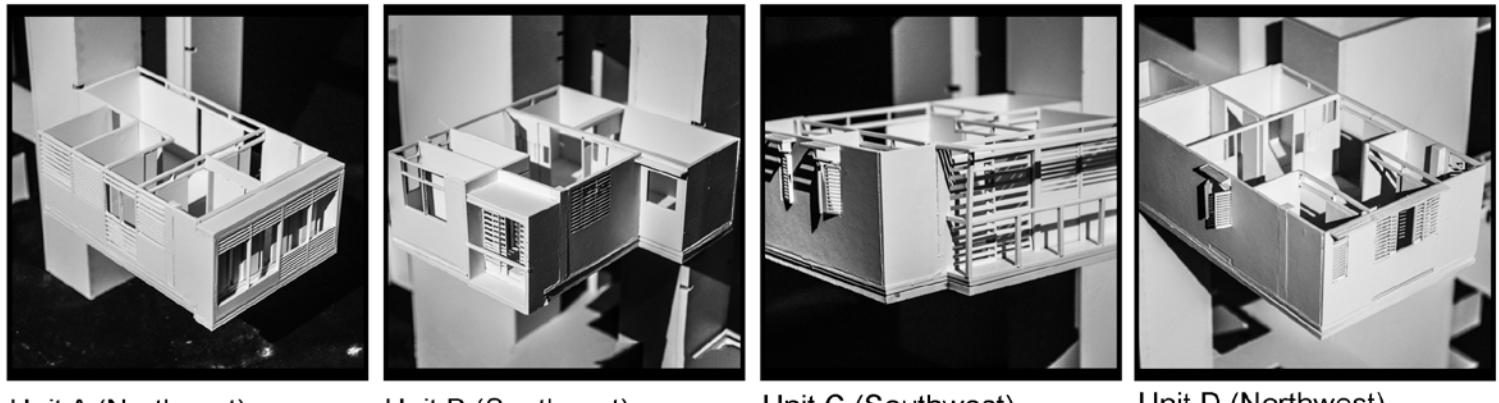
40th Floor - Elev. 120m



20th Floor - Elev.60m



1st Floor - Elev.9m



Unit A (Northeast) Unit B (Southeast) Unit C (Southwest) Unit D (Northwest)

[8] Dwelling unit study models for the cruciform high-rise typology. Results shown at elev. 9m, 60m, and 120m above street level - according to North, South, East, West (McKee, Suen, Chap, 2016)

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Bruelisauer, M., F. Meggers, E. Saber (2013). *Stuck in the Stack – Temperature Measurements of the Micro-climate around Split-type Condensing Units in High-Rise Buildings in Singapore*. Energy & Buildings 71, pp28-37. Elsevier.

Cheng, V., E. Ng (2005). *Comfort Temperatures for Naturally Ventilated Buildings in Hong Kong*. Architectural Science Review, Vol. 49.2, pp179-182, University of Sydney, Sydney.

Goncalves, J.C. and K. Bode (2011). *The Importance of Real Life Data to Support Environmental Claims for Tall Buildings*. CTBUH Journal Issue II pp24-29.

Koch-Nielsen, H. (2002). *Stay Cool: A Design Guide for the Built Environment in Hot Climates*. James & James (Science) Publishers.

Lau, S. (2002). *A Study of Microclimate Conditions in Outdoor Spaces of High-Rise Residential Buildings*. Proc. International Housing Conference in Hong Kong, pp865-871. Hong Kong.

Lau, S. (2010). *Users' Perceptions of Domestic Windows in Hong Kong: Challenging Daylighting-Based design Regulations.* Journal of Building Appraisal, Vol. 6, pp81-93, Macmillan Publishers, Ltd.

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Ng. E. (2005). *Regulate for Light, Air and Healthy Living*. Hong Kong Institute of Architects (HKIA) Journal, Issue 44, pp14-24, Hong Kong.

Nicol, J.F. (2004). *Adaptive Thermal Comfort Standards in the Hot-Humid Tropics*. Energy & Buildings, 36, pp628-637. Elsevier.

Ogwezi, B., G. Jeronimidis, G. Cook, J. Sakula, S. Gupta (2000). *Adaptive Buildings' Facades for Thermal Comfort in Hot-Humid Climates*. International Journal on Architectural Science, Vol. 1, Number 2, pp80-95, 2000.

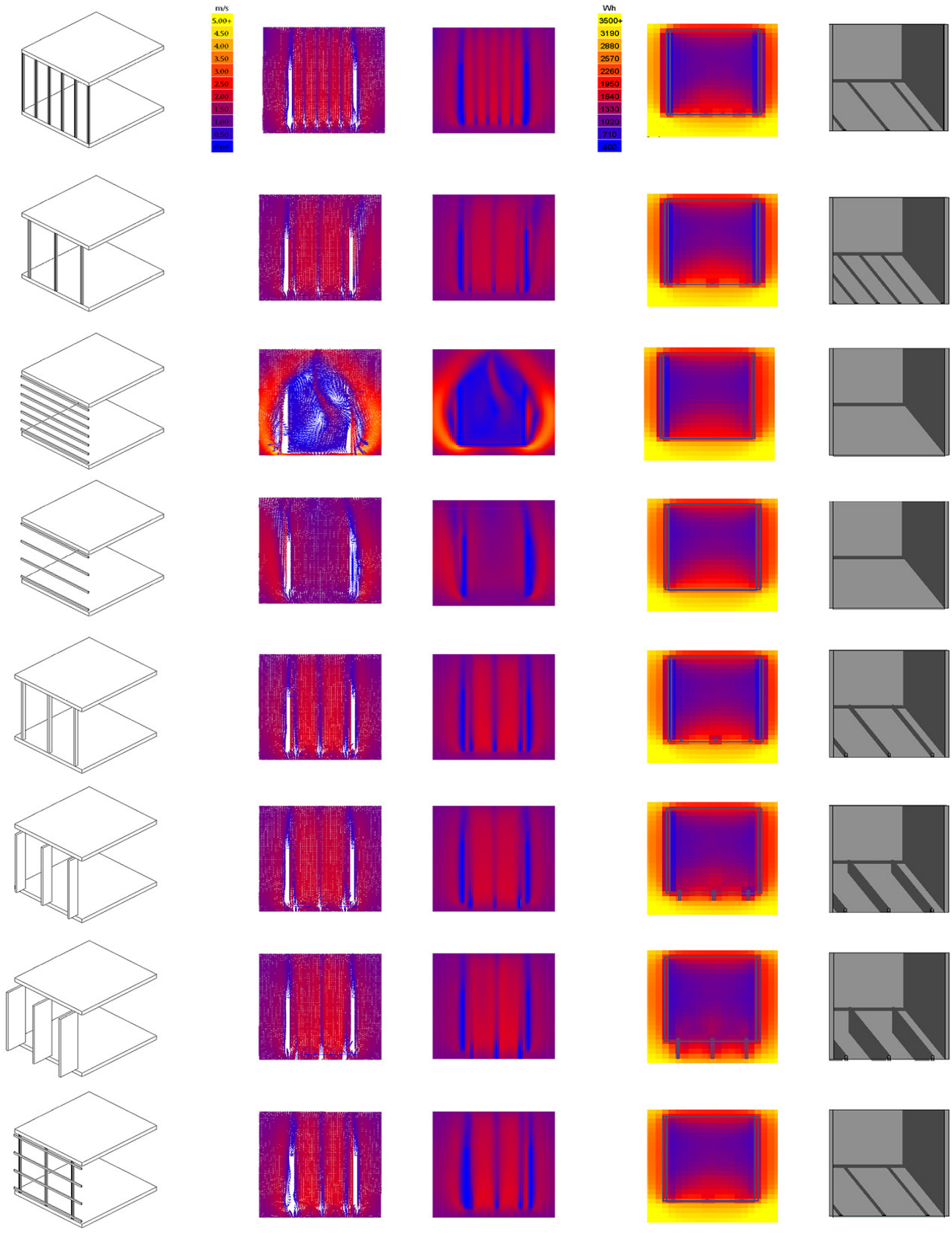
Wong, M., R. Hassel (2009). *Tall Buildings in Southeast Asia – A Humanist Approach to Tropical High-Rise*, Council on Tall Buildings and Urban Habitat Journal, Issue III, pp24-32, Council on Tall Buildings and Urban Habitat (CTBUH), Singapore.

Yannas, S. (1994). *Solar Energy and Housing Design. Vol. 1: Principles, Objectives, Guidelines.* Architectural Association, London.

Yannas, S. (2009). *What Can Buildings Tell Us, What Can We Tell Back*. PLEA 2009, Quebec, pp472-477.

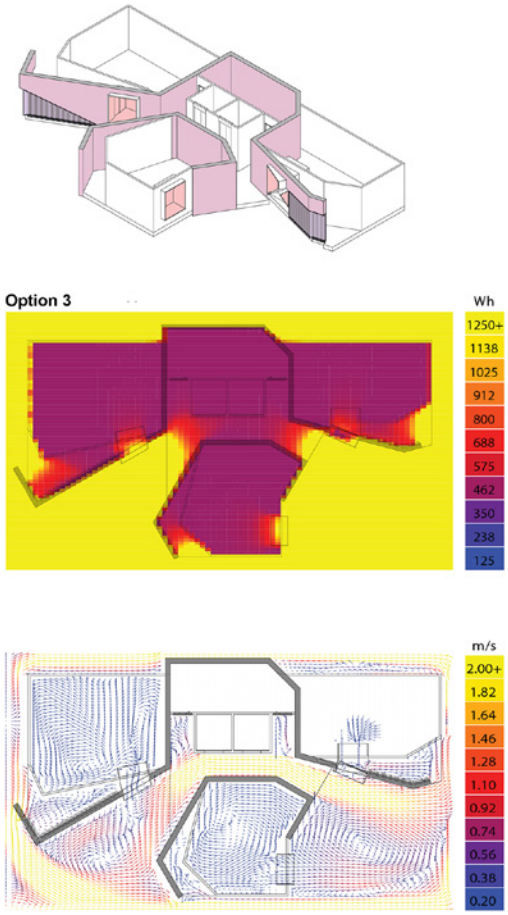
Yau, R. (2004). *Building Environmental and Sustainable Design Approach to Housing Developments*, Technical Practice Notes, pp1-8, Ove Arup & Partners Hong Kong Ltd., Hong Kong.

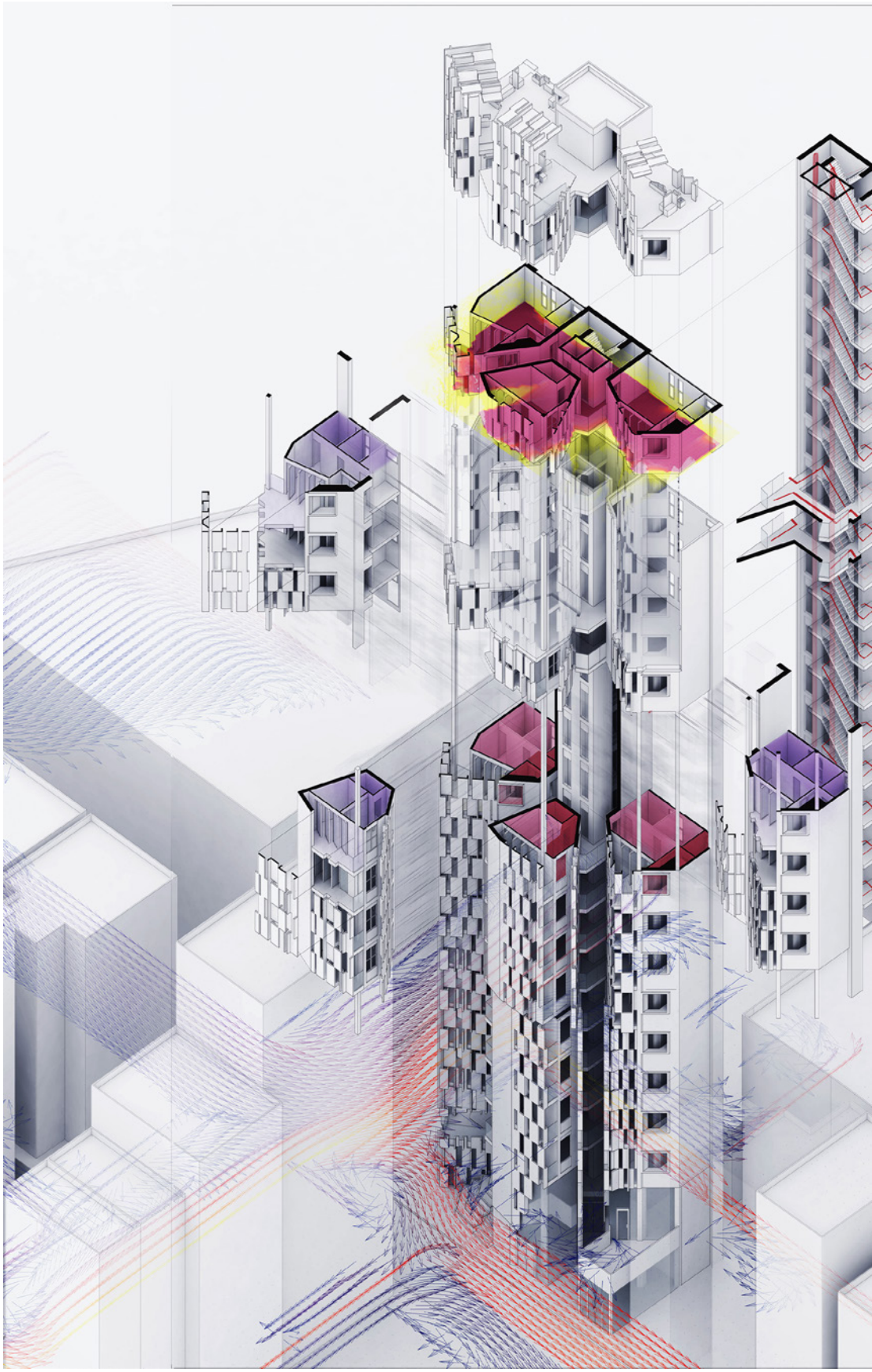
[9] Interior rendering of dwelling unit located in cruciform high-rise typology. Results show idesign retrofit for daylight, shading, and increased ventilation effectiveness (McKee, Suen, Chap, 2016)



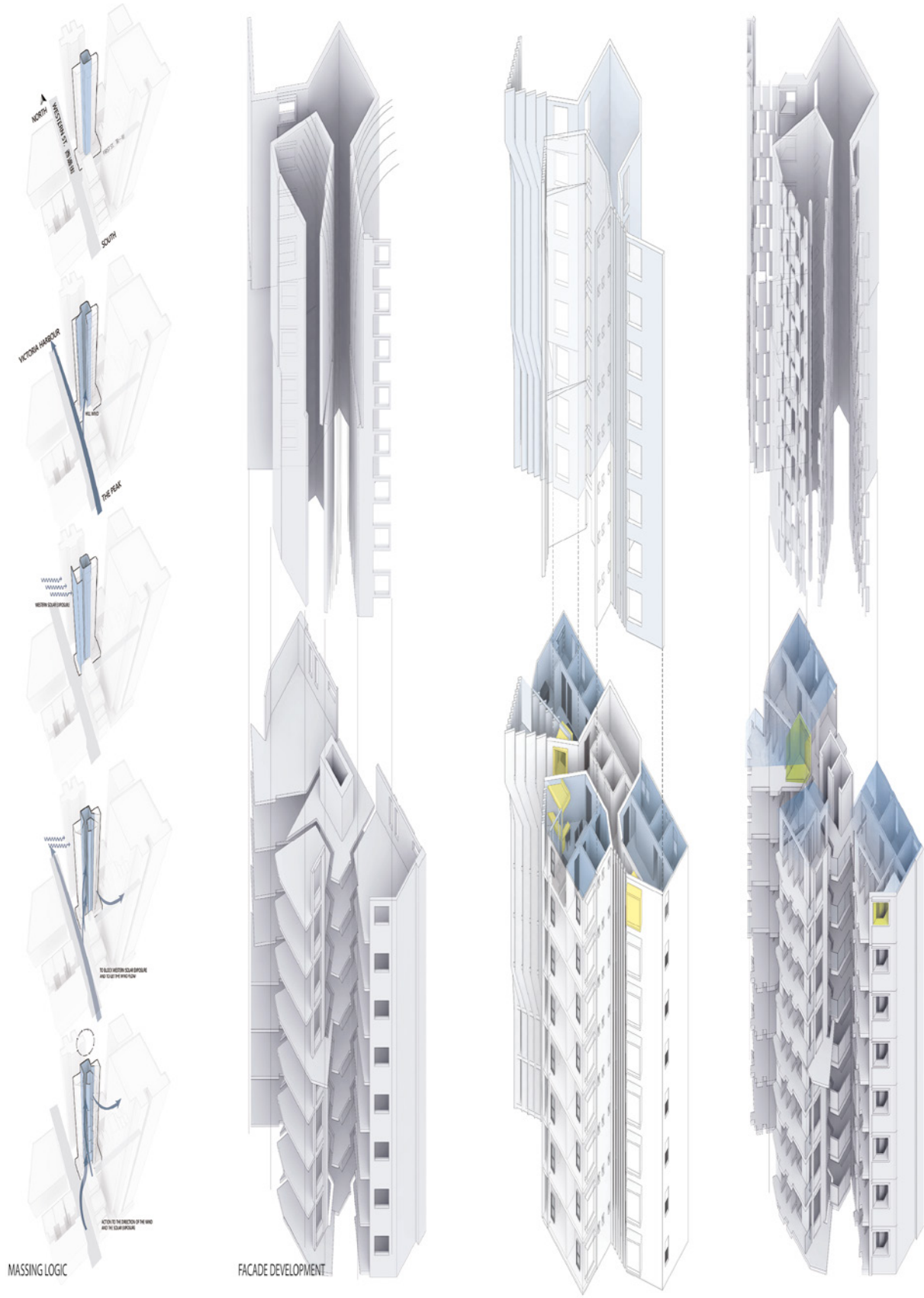

[10] Interior air flow, insolation and shadow simulations for adaptive prototypes for high-rise building enclosure (McKee, Ngan, Wu, 2017)

# Appendix

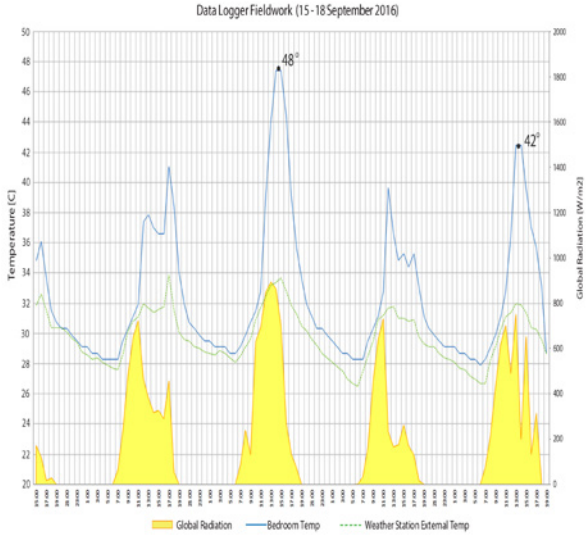


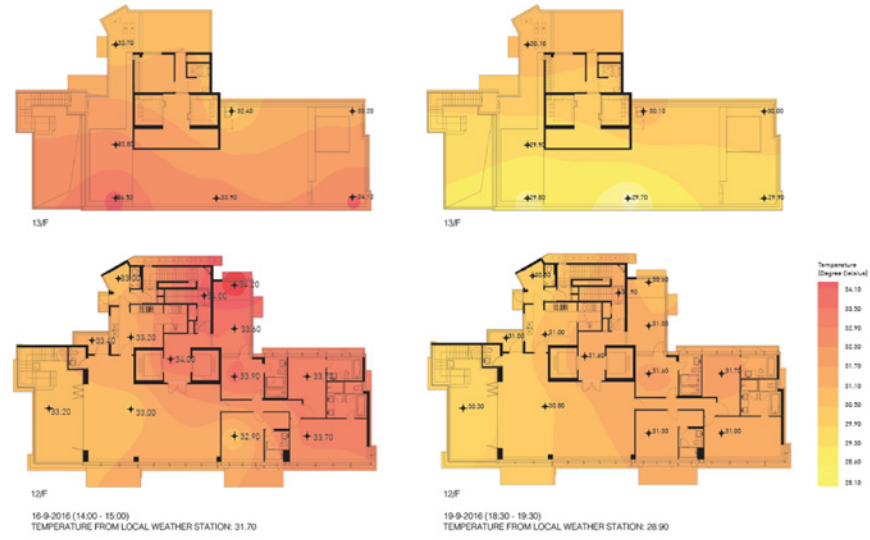



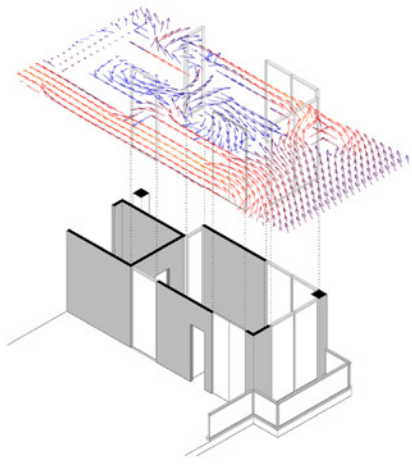
[11] Insolation and air flow simulation analysis of retrofitted trident high-rise typology located in residential density zone 2 (McKee, Hui, Yang, 2017)



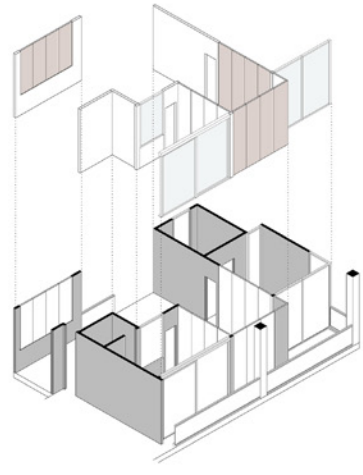

[12] Environmental screening - facade development studies for the trident high-rise typology located in residential density zone 2 (McKee, Hui, Yang, 2017)



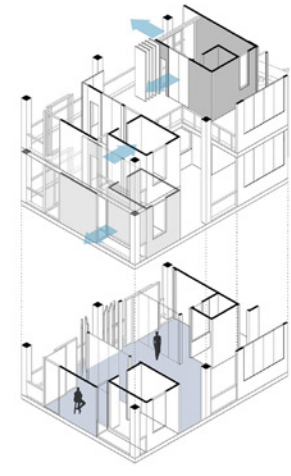



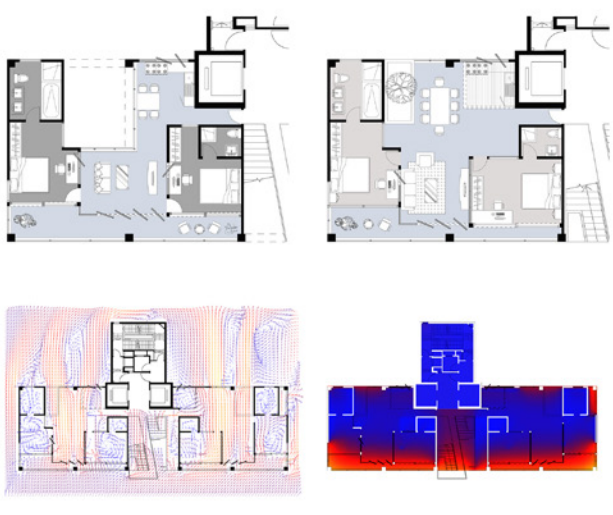
CLIMATE ADAPTATION



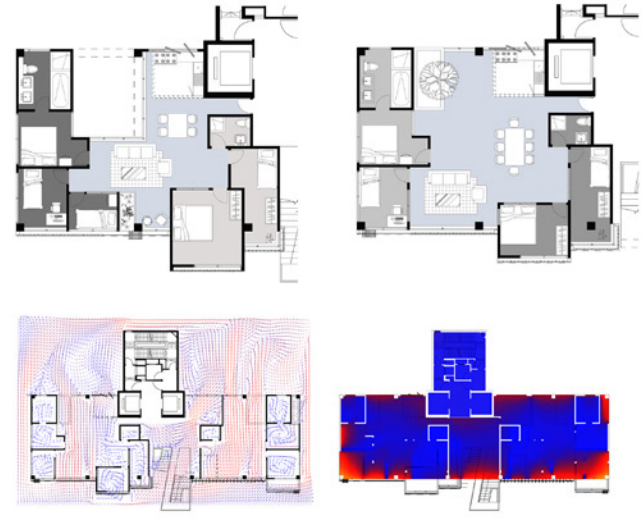
LAYERS MANIPULATION



PROGRAMME EXTENSION

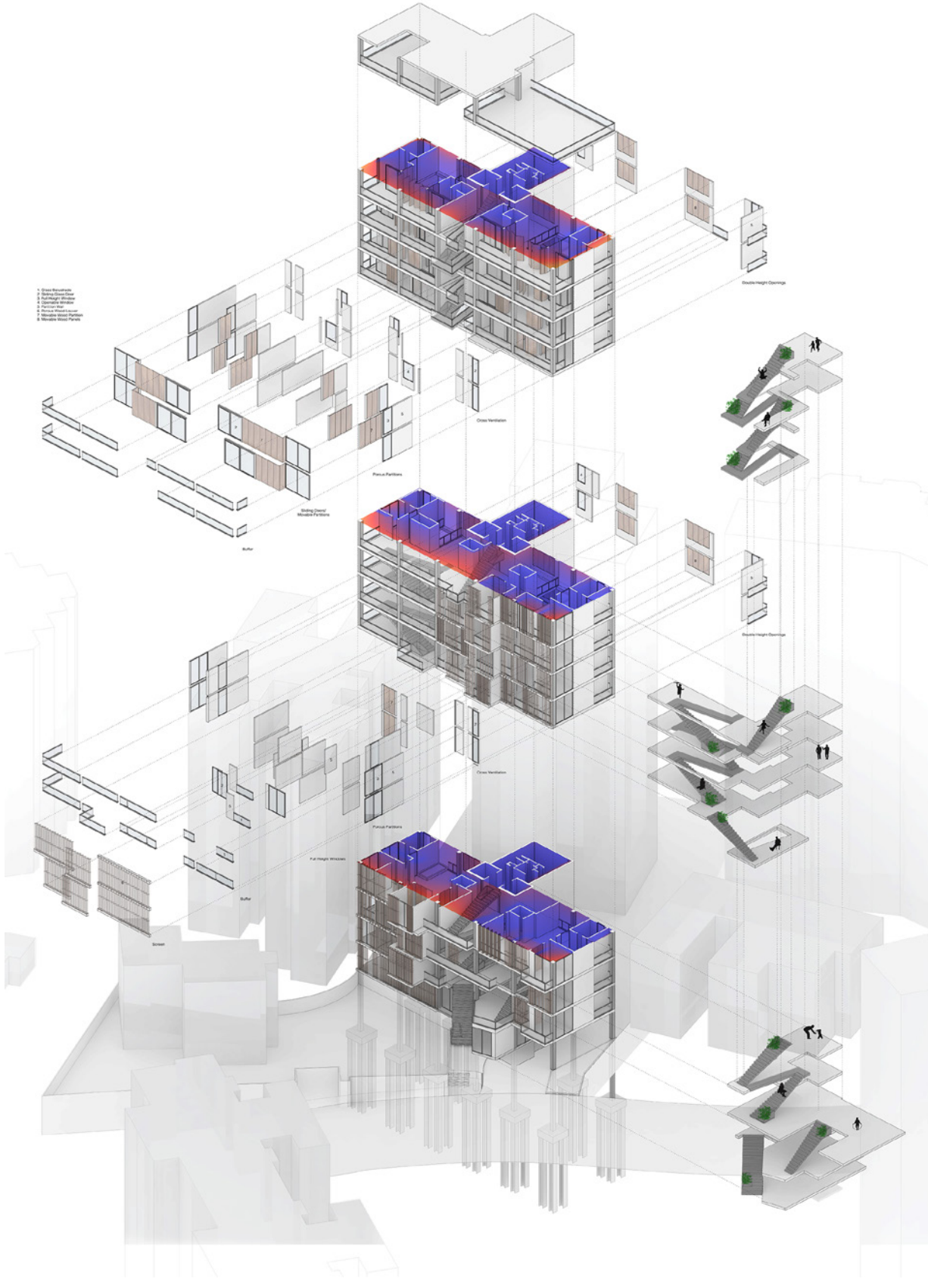


LARGE UNITS FLOORS

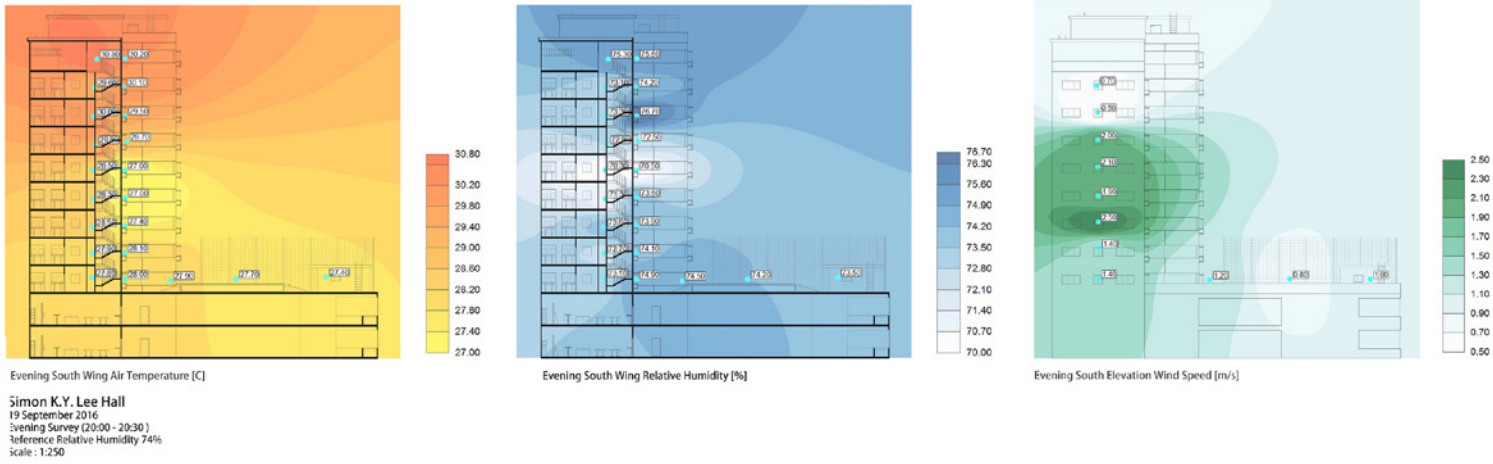


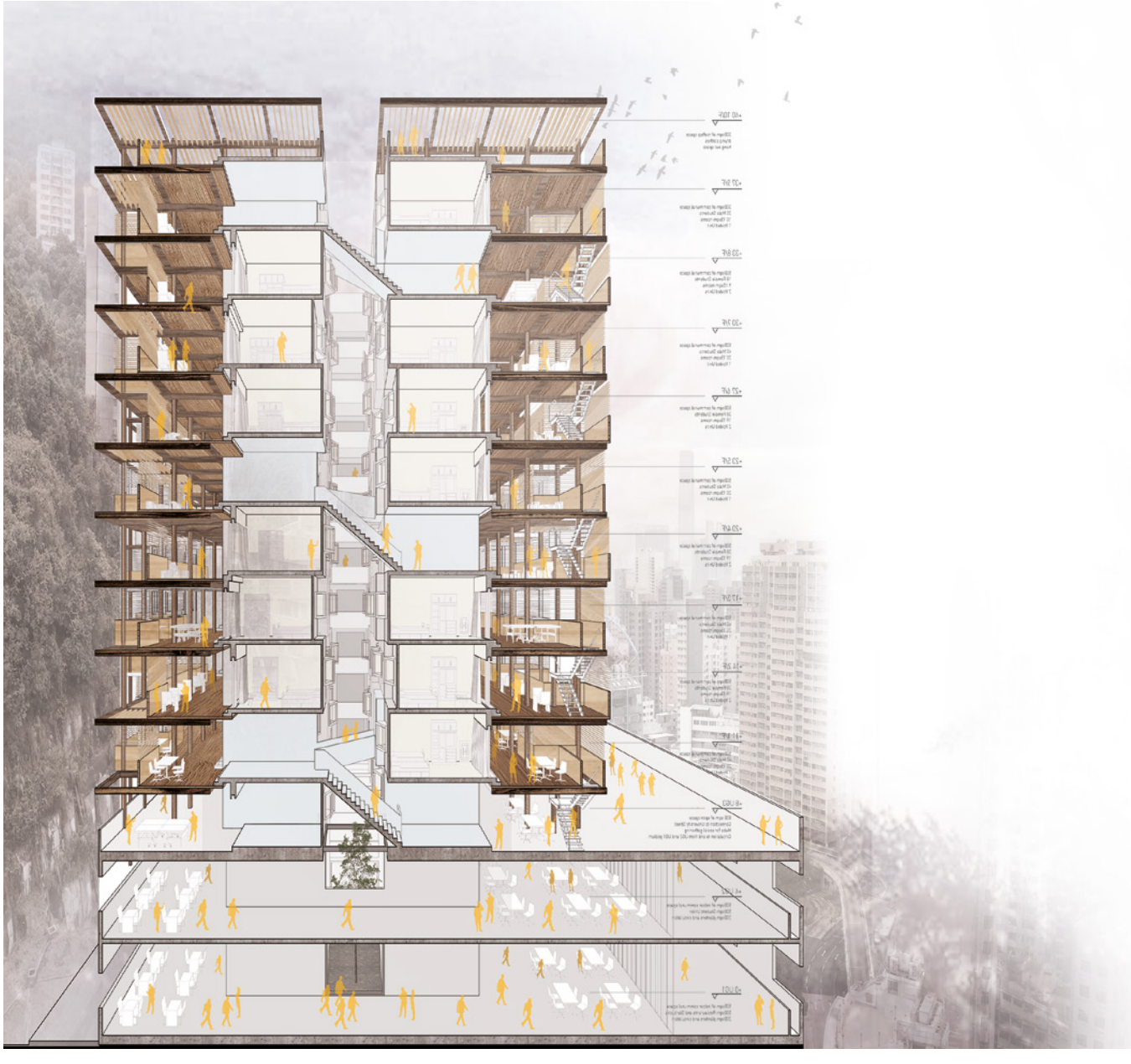
COMPACT UNITS FLOORS

[13] Fieldwork air temperature data collection and simulation results for airflow and insolation values for pencil tower high-rise typology located in residential density zone 3. Results show increased shading and ventilation effectiveness of adaptive design retrofits (McKee, Ngan, Wu, 2017)

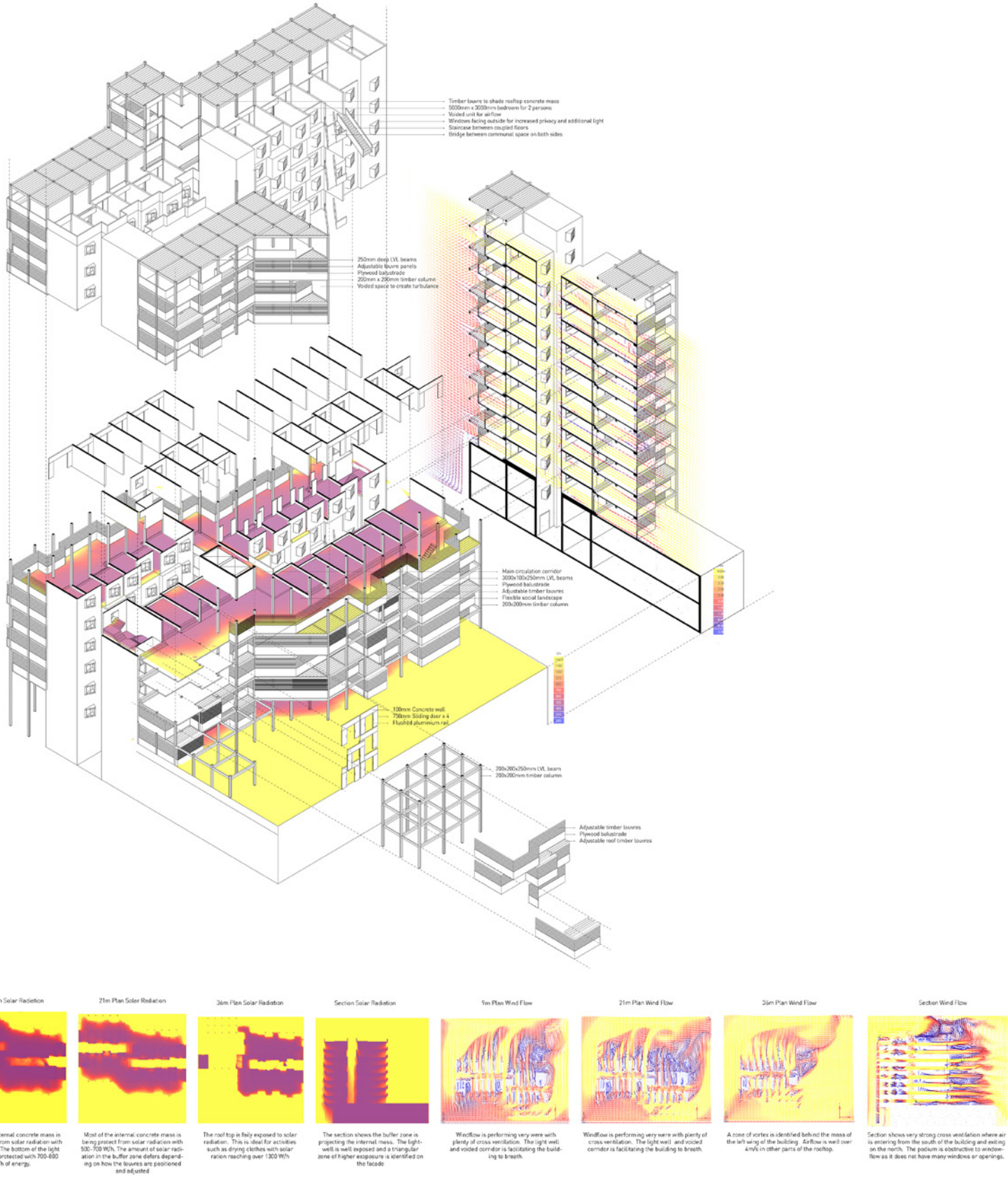



[14] Exploded axonometric drawing showing new environmental screening at lower, middle, and upper levels of the pencil-tower high-rise typology (McKee, Ngan, Wu, 2017)

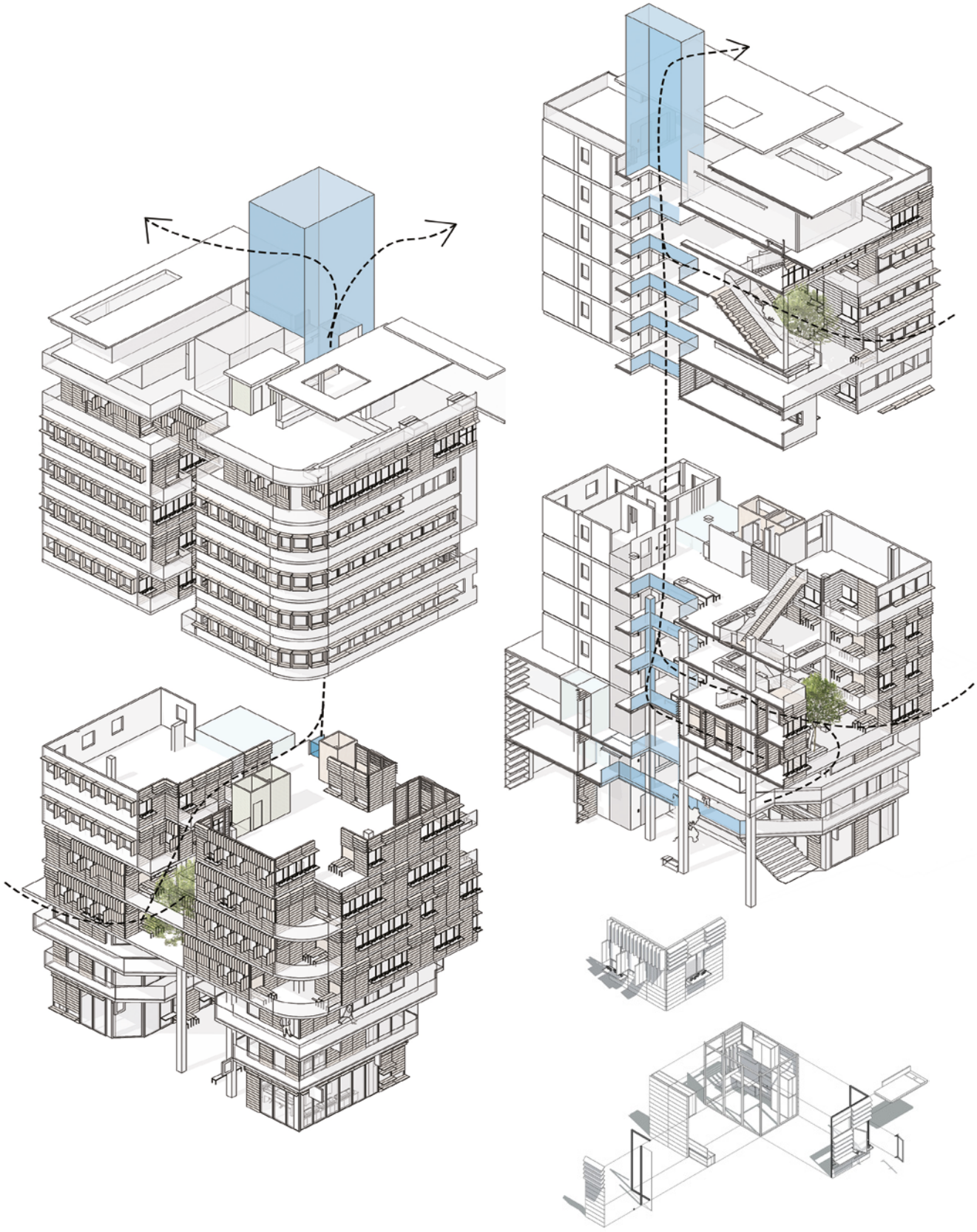


[13] Sectional axonometric showing expanded transitional space provided by adaptive design retrofit for slab-block high-rise typology located in residential density zone 3. (McKee, So, Ip, 2017)




[14] Exploded axonometric drawing showing new environmental screening and expanded transitional space for slab-block high-rise typology (McKee, So, Ip, 2017)



[15] Exploded axonometric showing expanded transitional space provided by adaptive design retrofit for 'tong lau' tenement high-rise typology located in residential density zone 1. (McKee, Chan, Lau, 2017)

The Department of Architecture educates students in an active culture of service, scholarship and invention. Uniquely situated at the crossroads of China and global influence, the Department takes the approach that design is best explored from a sophisticated understanding of both. With a multidisciplinary curriculum emphasizing technology, history and culture, students gain broad knowledge and skills in the management of the environmental, social, and aesthetic challenges of contemporary architectural practice. With opportunities for design workshops, international exchanges, and study travel, graduates of the Department of Architecture are well prepared for contribution to both international and local communities of architects and designers.