

# Zhe WANG

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## INTRO

I am an Assistant Professor working with the Department of Civil and Environmental Engineering of the Hong Kong University of Science and Technology. My current research is about the application of artificial intelligence in smart building and low carbon city, majorly from two aspects. First, I am looking at how to leverage advanced control techniques (e.g. Reinforcement Learning, Model Predictive Control, etc.) to enhance building performance. Second, I am interested in how machine learning techniques could help to inform decision making on building performance.

Before joining HKUST, I worked as a Project Scientist in Lawrence Berkeley National Lab on smart building control, as a Postdoctoral Scholar in University of California, Berkeley on data-driven personal comfort model and devices, and as an Energy Consultant with World Bank on Urban Scale Building Energy Efficiency and Renewable Energy in China. I was awarded the Second Class Award of Chinese State Science and Technology Prize (2019), the First Class Award of Beijing Science and Technology Prizes (2018), and was invited to give a speech on the Seventh-Round High-level Consultation on U.S.-China People to People Exchange, as the only representative of Chinese young scholar.

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## EMPLOYMENT

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|--------------------------|---|------------------|
| <i>2021.11 till now</i>  | <b>Hong Kong University of Science and Technology, Assistant Professor</b>  | <b>Hong Kong</b> |
| <br>                     |   |                  |
| <i>2018.07 – 2021.10</i> | <b>Lawrence Berkeley National Lab, Project Scientist</b>  | <b>Berkeley</b>  |
|                          | <ul style="list-style-type: none"><li>➤ Co-PI, AlphaBuilding – Reinforcement Learning for Building Control, LBNL funded (LBNL LDRD: BU21-036)<ul style="list-style-type: none"><li>• Develop virtual environments of buildings for RL training</li><li>• Develop RL controller for buildings using DDPG algorithm</li><li>• Design multi-agent RL structure to enhance scalability</li></ul></li><li>➤ Leading researcher, Sensor Data Integration - Integrating Sensor Data with Physics-Based Models, US Department of Energy funded (US DOE: EE-5B37579)<ul style="list-style-type: none"><li>• Infer building thermal dynamics using connected smart thermostat</li><li>• Estimate demand response potential of US residential buildings</li></ul></li><li>➤ Key researcher, Hierarchical Occupancy Responsive Model Predictive Control at Room, Building and Campus Levels, US Department of Energy funded (US DOE: EE-5B24502)<ul style="list-style-type: none"><li>• Develop building and campus level Model Predictive Control for buildings</li><li>• Data analytics of the field test results</li></ul></li><li>➤ Key researcher, End-Use Load Profiles for the U.S. Building Stock, US Department of Energy funded (US DOE: EE-5B35033)<ul style="list-style-type: none"><li>• Occupant behavior modelling to produce realistic building load shape</li><li>• Propose data-driven approach to generate building load</li><li>• Compare the generated load with real smart meter data</li></ul></li></ul> |                  |
| <br>                     |   |                  |
| <i>2017.10-2018.06</i>   | <b>UC Berkeley, Postdoc Researcher</b>  | <b>Berkeley</b>  |
|                          | <ul style="list-style-type: none"><li>➤ Key researcher, Data-driven personal comfort model and wearable comfort devices, NSF funded (0.5M USD)<ul style="list-style-type: none"><li>• Develop and test energy efficient comfort wearable to address personal demand</li><li>• Develop data-driven model to predict individual comfort demands</li></ul></li></ul>   |                  |

2016.12-2018.06	<b>World Bank, Energy Consultant</b>	<b>Beijing/Berkeley</b>
	<ul style="list-style-type: none"> <li>➤ Joint research with Ministry of Housing, Urban and Rural Development: Urban Scale Building Energy Efficiency and Renewable Energy Project <ul style="list-style-type: none"> <li>• Assist the project manager by overseeing the technical progress</li> <li>• Provide technical supports to the sub-contractors</li> </ul> </li> </ul>	

## EDUCATION

2011.08-2017.07	<b>Tsinghua University</b>	<b>Ph.D. in Building Science</b>
	<ul style="list-style-type: none"> <li>➤ Visiting scholar in <i>Harvard University</i>, 2015</li> <li>➤ Recipient of the <i>National Scholarship</i> (2012), <i>Boeing Scholarship</i> (2015), <i>Outstanding Graduate of Beijing</i> (2017)</li> </ul>	
2016.08-2017.07	<b>Schwarzman College, Tsinghua University</b>	<b>Master in Global Affairs</b>
	<ul style="list-style-type: none"> <li>➤ Invited to give a speech on the Seventh-Round High-level Consultation on U.S.-China People to People Exchange (Chaired by Chinese Vice Premier Yandong Liu and U.S. Secretary of State John Kerry), as the <i>ONLY</i> representative of Chinese young scholar</li> <li>➤ Selected as a Student Council Member (12 out of 110)</li> </ul>	
2013.10-2014.09	<b>University of Cambridge</b>	<b>M.Phil. in Energy Technology</b>
	<ul style="list-style-type: none"> <li>➤ Recipient of the <i>Wing Yip Scholarship, Cambridge Overseas Trust</i> (2013)</li> </ul>	
2008.09-2011.07	<b>Tsinghua University</b>	<b>Bachelor in Economics</b>
	<ul style="list-style-type: none"> <li>➤ Cumulative GPA 92.8/100, <b>ranking 1<sup>st</sup></b> /126</li> </ul>	
2007.09-2011.07	<b>Tsinghua University</b>	<b>Bachelor in Civil Engineering</b>
	<ul style="list-style-type: none"> <li>➤ Cumulative GPA 91.3/100, <b>ranking 1<sup>st</sup></b> /29</li> <li>➤ Recipient of the <i>National Scholarship</i> (2009, 2010), <i>Boeing Scholarship</i> (2011)</li> <li>➤ Recipient of the <i>Outstanding Undergraduate of Beijing</i> (2011)</li> </ul>	

## RESEARCH & INTERNSHIP

2015.02-2017.06	<b>UCL-THU Joint Research, Chief Research Assistant</b>	<b>London/Beijing</b>
	<ul style="list-style-type: none"> <li>➤ Developing indoor environmental quality sensors</li> <li>➤ Monitoring and analyzing building energy efficiency and indoor environment quality</li> </ul>	
2015.07-2015.08	<b>AECOM/Asian Development Bank, Energy Analyst</b>	<b>Beijing</b>
	<ul style="list-style-type: none"> <li>➤ Energy consumption prediction, demand side management, energy flow chart</li> </ul>	
2012.05-2012.07	<b>MIT-THU Joint Studio, Energy Designer</b>	<b>Beijing/Jinan</b>
	<ul style="list-style-type: none"> <li>➤ Energy Analyst: urban micro-climate simulation</li> </ul>	
2010.07-2010.08	<b>Swire Properties, Internship</b>	<b>Hong Kong</b>
	<ul style="list-style-type: none"> <li>➤ Consultant: energy efficiency improvement of building HVAC system</li> </ul>	

## OPEN-SOURCE TOOL

<i>MPCPy</i>	Python-based open-source platform for model predictive control in buildings <a href="https://github.com/lbl-srg/MPCPy">https://github.com/lbl-srg/MPCPy</a>
<i>Modelica Buildings Library</i>	Dynamic simulation models for building energy and control systems <a href="https://github.com/lbl-srg/modelica-buildings">https://github.com/lbl-srg/modelica-buildings</a>

## ACADEMIC SERVICE

2021 till now	Associate Editor, <i>Frontiers in Built Environment</i>
2020 till now	Editor,

2020	<i>Building Simulation, Building Energy Conservation</i> Grant Proposal Reviewer <i>The Dunhill Medical Trust, UK</i>
2020, 2021	Member of Technical Program Committee, <i>First International Workshop on Reinforcement Learning for Energy Management in Buildings &amp; Cities (RLEM)</i> , <a href="https://rlem-workshop.net/">https://rlem-workshop.net/</a>
till now	Reviewer, <i>Applied Energy, Energy, Building and Environment, Energy and Building, Journal of Building Engineering, Building Simulation, Environmental Science and Pollution Research, Science and Technology for the Built Environment, SoftwareX, Journal of Building Performance Simulation, Applied Thermal Engineering, Advanced Engineering Informatics, Frontiers in Built Environment, International Journal of Biometeorology, Journal of Asian Architecture and Building Engineering, Journal of the Taiwan Institute of Chemical Engineer, Sustainable Cities and Society, Engineering</i>

## AWARD

1. Key Technology for the Environmental and Energy-Efficient Design of Green Building, Second Class Award of 2019 Chinese State Science and Technology Prize (2019 年国家科学技术进步奖二等奖), Award Number: 2019-J-22101-2-01-R09
2. Key Technology for the Environmental and Energy-Efficient Design of Green Building, First Class Award of 2018 Beijing Science and Technology Prize (2018 年北京市科学技术奖一等奖)
3. Environment Monitoring and Energy Conservation Technology of Large Commercial Buildings, First Class Award of 2020 Huaxia Construction Prize (2020 华夏建设科学技术一等奖)

## PATENT

1. Lin, BR., Zhao, HT., and **Wang, Z.**, A Waste Heat Recovery System Designed for Dishwasher. Chinese Patent Number: ZL 201320328067.9

## PUBLICATION

(#: contribute equally; \*: corresponding author)

1. **Wang, Z.**, Chen, B., Li, H. and Hong, T., 2021. AlphaBuilding ResCommunity: A multi-agent virtual testbed for community-level load coordination. *Advances in Applied Energy*, 4, p.100061.
2. **Wang, Z.**, Hong, T. and Li, H., 2021. Informing the planning of rotating power outages in heat waves through data analytics of connected smart thermostats for residential buildings. *Environmental Research Letters*, 16(7), p.074003.
3. **Wang, Z.**, Hong, T., Li, H. and Piette, M.A., 2021. Predicting city-scale daily electricity consumption using data-driven models. *Advances in Applied Energy*, 2, p.100025.
4. **Wang, Z.** and Hong, T., 2020. Reinforcement Learning for Building Controls: The opportunities and challenges. *Applied Energy*, 269, p.115036.
5. **Wang, Z.**, Hong, T. and Piette, M.A., 2020. Building thermal load prediction through shallow machine learning and deep learning. *Applied Energy*, 263, p.114683.
6. **Wang, Z.** and Hong, T., 2020. Learning occupants' indoor comfort temperature through a Bayesian inference approach for office buildings in United States. *Renewable and Sustainable Energy Reviews*, 119, p.109593.
7. **Wang, Z.** and Hong, T., 2020. Generating realistic building electrical load profiles through the Generative Adversarial Network (GAN). *Energy and Buildings*, p.110299.
8. **Wang, Z.**, Hong, T., Piette, M.A. and Pritoni, M. 2019, Inferring occupant counts from Wi-Fi data in buildings through machine learning, *Building and Environment*, 158, pp. 281-294.
9. **Wang, Z.**, Parkinson, T., Li, P., Lin, B. and Hong, T., 2019. The Squeaky wheel: Machine learning for anomaly detection in subjective thermal comfort votes. *Building and Environment*, 151, pp.219-227.
10. **Wang, Z.**, Zhang, H., He, Y., Luo, M., Li, Z., Hong, T. and Lin, B., 2020. Revisiting individual and group differences in thermal comfort based on ASHRAE database. *Energy and Buildings*, 219, p.110017.
11. **Wang, Z.**, Wang, J., He, Y., Liu, Y., Lin, B. and Hong, T., 2020. Dimension analysis of subjective thermal comfort metrics

based on ASHRAE Global Thermal Comfort Database using machine learning. *Journal of Building Engineering*, 29, p.101120.

12. **Wang, Z.**, Hong, T. and Piette, M.A., 2019. Predicting plug loads with occupant count data through a deep learning approach. *Energy*, 181, pp.29-42.
13. **Wang, Z.**, Warren, K., Luo, M., He, X., Zhang, H., Arens, E., Chen, W., He, Y., Hu, Y., Jin, L. and Liu, S., 2019. Evaluating the comfort of thermally dynamic wearable devices. *Building and Environment*, p.106443.
14. **Wang, Z.**, Hong, T. and Piette, M.A., 2019. Data fusion in predicting internal heat gains for office buildings through a deep learning approach. *Applied Energy*, 240, pp.386-398.
15. **Wang, Z.**, Hong, T. and Jia, R., 2018. Buildings. Occupants: a Modelica package for modelling occupant behaviour in buildings. *Journal of Building Performance Simulation*, pp.1-12.
16. **Wang, Z.**, Luo, M., Geng, Y., Lin, B. and Zhu, Y., 2018. A model to compare convective and radiant heating systems for intermittent space heating. *Applied Energy*, 215, pp.211-226.
17. **Wang, Z.**, de Dear, R., Luo, M., Lin, B., He, Y., Ghahramani, A. and Zhu, Y., 2018. Individual difference in thermal comfort: A literature review. *Building and Environment*, 138, pp. 181-193 (highly cited paper)
18. **Wang, Z.**, Zhao, Z., Lin, B., Zhu, Y. and Ouyang, Q., 2015. Residential heating energy consumption modeling through a bottom-up approach for China's Hot Summer–Cold Winter climatic region. *Energy and Buildings*, 109, pp.65-74.
19. **Wang, Z.**, Zhao, H., Lin, B., Zhu, Y., Ouyang, Q. and Yu, J., 2015. Investigation of indoor environment quality of Chinese large-hub airport terminal buildings through longitudinal field measurement and subjective survey. *Building and Environment*, 94, pp.593-605.
20. **Wang, Z.**, de Dear, R., Lin, B., Zhu, Y. and Ouyang, Q., 2015. Rational selection of heating temperature set points for China's hot summer–Cold winter climatic region. *Building and Environment*, 93, pp.63-70.
21. **Wang, Z.**, Lin, B. and Zhu, Y., 2015. Modeling and measurement study on an intermittent heating system of a residence in Cambridgeshire. *Building and Environment*, 92, pp.380-386.
22. Liu, S.<sup>\*,#</sup>, **Wang, Z.**<sup>\*,#</sup>, Schiavon, S., He, Y., Luo, M., Zhang, H. and Arens, E., 2020. Predicted percentage dissatisfied with vertical temperature gradient. *Energy and Buildings*, p.110085.
23. Wang, J.<sup>#</sup>, **Wang, Z.**<sup>#</sup>, Zhou, D. and Sun, K., 2019. Key issues and novel optimization approaches of industrial waste heat recovery in district heating systems. *Energy*, p.116005.
24. Wang, J.<sup>#</sup>, **Wang, Z.**<sup>\*,#</sup>, de Dear, R., Luo, M., Ghahramani, A. and Lin, B., 2018. The uncertainty of subjective thermal comfort measurement. *Energy and Buildings*, 181, pp.38-49.
25. Liu, Y.<sup>#</sup>, **Wang, Z.**<sup>#</sup>, Lin, B., Hong, J. and Zhu, Y., 2018. Occupant satisfaction in Three-Star-certified office buildings based on comparative study using LEED and BREEAM. *Building and Environment*, 132, pp.1-10.
26. Touzani, S.<sup>#</sup>, Prakash, A.K.<sup>#</sup>, **Wang, Z.**<sup>#</sup>, Agarwal, S., Pritoni, M., Kiran, M., Brown, R. and Granderson, J., 2021. Controlling distributed energy resources via deep reinforcement learning for load flexibility and energy efficiency. *Applied Energy*, 304, p.117733.
27. Luo, M., **Wang, Z.**<sup>\*</sup>, Ke, K., Cao, B., Zhai, Y. and Zhou, X., 2018. Human metabolic rate and thermal comfort in buildings: The problem and challenge. *Building and Environment*, 131, pp. 44-52
28. Luo, N., **Wang, Z.**, Blum, D., Weyandt, C., Bourassa, N., Piette, M.A. and Hong, T., 2022. A three-year dataset supporting research on building energy management and occupancy analytics. *Scientific Data*, 9(1), pp.1-15.
29. Pinto, G., **Wang, Z.**, Roy, A., Hong, T. and Capozzoli, A., 2022. Transfer learning for smart buildings: A critical review of algorithms, applications, and future perspectives. *Advances in Applied Energy*, p.100084.
30. Li, H., **Wang, Z.** and Hong, T., 2021. A synthetic building operation dataset. *Scientific data*, 8(1), pp.1-13.
31. Li, H., **Wang, Z.**, Hong, T. and Piette, M.A., 2021. Energy Flexibility of Residential Buildings: A Systematic Review of Characterization and Quantification Methods and Applications. *Advances in Applied Energy*, p.100054.
32. Li, H., **Wang, Z.**, Hong, T., Parker, A. and Neukomm, M., 2021. Characterizing patterns and variability of building electric load profiles in time and frequency domains. *Applied Energy*, 291, p.116721.
33. Wang, M., **Wang, Z.**, Geng, Y. and Lin, B., 2021. Interpreting the neural network model for HVAC system energy data mining. *Building and Environment*, p.108449.
34. Li, H., **Wang, Z.** and Hong, T., 2021. Occupant-Centric key performance indicators to inform building design and operations. *Journal of Building Performance Simulation*, pp.1-29.

35. Hong, T., **Wang, Z.**, Luo, X. and Zhang, W., 2020. State-of-the-art on research and applications of machine learning in the building life cycle. *Energy and Buildings*, p.109831.
36. Jiang, Y., **Wang, Z.**, Lin, B. and Mumovic, D., 2020. Development of a health data-driven model for a thermal comfort study. *Building and Environment*, p.106874.
37. Liu, Y., **Wang, Z.**, Zhang, Z., Hong, J. and Lin, B., 2018. Investigation on the Indoor Environment Quality of health care facilities in China. *Building and Environment*, 141, pp. 273-287
38. Luo, M., **Wang, Z.**, Zhang, H., Arens, E., Filingeri, D., Jin, L., Ghahramani, A., Chen, W., He, Y. and Si, B., 2020. High-density thermal sensitivity maps of the human body. *Building and Environment*, 167, p.106435.
39. Luo, M., **Wang, Z.**, Brager, G., Cao, B. and Zhu, Y., 2018. Indoor climate experience, migration, and thermal comfort expectation in buildings. *Building and Environment*, 141, pp. 262-272
40. Lin, B., **Wang, Z.**, Sun, H., Zhu, Y. and Ouyang, Q., 2016. Evaluation and comparison of thermal comfort of convective and radiant heating terminals in office buildings. *Building and Environment*, 106, pp.91-102.
41. Lin, B., **Wang, Z.**, Liu, Y., Zhu, Y. and Ouyang, Q., 2016. Investigation of winter indoor thermal environment and heating demand of urban residential buildings in China's hot summer–Cold winter climate region. *Building and Environment*, 101, pp.9-18.
42. Su, Y., Cheng, H., **Wang, Z.** and Wang, L., 2022. Impacts of the COVID-19 lockdown on building energy consumption and indoor environment: A case study in Dalian, China. *Energy and Buildings*, p.112055.
43. Guo, X., Lee, K., **Wang, Z.** and Liu, S., 2021. Occupants' satisfaction with LEED-and non-LEED-certified apartments using social media data. *Building and Environment*, p.108288.
44. He, Y., Zhou, Y., **Wang, Z.**, Liu, J., Liu, Z. and Zhang, G., 2021. Quantification on fuel cell degradation and techno-economic analysis of a hydrogen-based grid-interactive residential energy sharing network with fuel-cell-powered vehicles. *Applied Energy*, 303, p.117444.
45. Chen, B., Jin, M., **Wang, Z.**, Hong, T. and Bergés, M., 2020, November. Towards Off-policy Evaluation as a Prerequisite for Real-world Reinforcement Learning in Building Control. In *Proceedings of the 1st International Workshop on Reinforcement Learning for Energy Management in Buildings & Cities* (pp. 52-56).
46. Hong, T., Chen, C.F., **Wang, Z.** and Xu, X., 2020. Linking human-building interactions in shared offices with personality traits. *Building and Environment*, 170, p.106602.
47. Jiang, Y., Luo, Z., **Wang, Z.** and Lin, B., 2019. Review of thermal comfort infused with the latest big data and modeling progresses in public health. *Building and Environment*, 164, p.106336.
48. He, Y., Chen, W., **Wang, Z.** and Zhang, H., 2019. Review of fan-use rates in field studies and their effects on thermal comfort, energy conservation, and human productivity. *Energy and Buildings*, 194, pp. 140-162.
49. Geng, Y., Ji, W., **Wang, Z.**, Lin, B. and Zhu, Y., 2018. A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction. *Energy and Buildings*. 183, pp.500-514. (highly cited paper)
50. Lin, B., Liu, Y., **Wang, Z.**, Pei, Z. and Davies, M., 2016. Measured energy use and indoor environment quality in green office buildings in China. *Energy and Buildings*, 129, pp.9-18.
51. Cho, B., Dayrit, T., Gao, Y., **Wang, Z.**, Hong, T., Sim, A. and Wu, K., 2020, December. Effective Missing Value Imputation Methods for Building Monitoring Data. In *2020 IEEE International Conference on Big Data (Big Data)* (pp. 2866-2875). IEEE.
52. He, Y., Arens, E., Li, N., **Wang, Z.**, Zhang, H., Yongga, A. and Yuan, C., 2020. Modeling solar radiation on a human body indoors by a novel mathematical model. *Building and Environment*, p.107421.
53. Wang, Z., Yu, H., Luo, M., **Wang, Z.**, Zhang, H. and Jiao, Y., 2019. Predicting older people's thermal sensation in building environment through a machine learning approach: Modelling, interpretation, and application. *Building and Environment*, 161, p.106231.
54. Wang, J., Hua, J., Fu, L., **Wang, Z.** and Zhang, S., 2019. A theoretical fundamental investigation on boilers equipped with vapor-pump system for Flue-Gas Heat and Moisture Recovery. *Energy*, 171, pp.956-970.
55. Luo, M., Ke, Z., Ji, W., **Wang, Z.**, Cao, B., Zhou, X. and Zhu, Y., 2019. The time-scale of thermal comfort adaptation in heated and unheated buildings. *Building and Environment*, 151, pp.175-186.
56. Geng, Y., Yu, J., Lin, B., **Wang, Z.** and Huang, Y., 2017. Impact of individual IEQ factors on passengers' overall satisfaction in Chinese airport terminals. *Building and Environment*, 112, pp.241-249.

57. He, Y., Zhou, Y., Yuan, J., Liu, Z., **Wang, Z.** and Zhang, G., 2021. Transformation towards a carbon-neutral residential community with hydrogen economy and advanced energy management strategies. *Energy Conversion and Management*, 249, p.114834.
58. Chen, C.F., De Simone, M., Yilmaz, S., Xu, X., **Wang, Z.**, Hong, T. and Pan, Y., 2021. Intersecting heuristic adaptive strategies, building design and energy saving intentions when facing discomfort environment: A cross-country analysis. *Building and Environment*, 204, p.108129.
59. Li, Z., Lin, B., Zheng, S., Liu, Y., **Wang, Z.** and Dai, J., 2020, August. A review of operational energy consumption calculation method for urban buildings. *Building Simulation*, Vol. 13, No. 4, pp. 739-751
60. Hong, T., Macumber, D., Li, H., Fleming, K. and **Wang, Z.**, 2020, June. Generation and representation of synthetic smart meter data. *Building Simulation*, Vol. 13, No. 4, pp. 1205–1220
61. Ghahramani, A., Galicia, P., Lehrer, D., Varghese, Z., **Wang, Z.** and Pandit, Y., 2020. Artificial Intelligence for Efficient Thermal Comfort Systems: Requirements, Current Applications and Future Directions. *Frontiers in Built Environment*, 6.
62. Luo, M., Arens, E., Zhang, H., Ghahramani, A. and **Wang, Z.**, 2018. Thermal comfort evaluated for combinations of energy-efficient personal heating and cooling devices. *Building and Environment*, 143, pp.206-216.
63. Taylor, J., Liu, Y., Lin, B., Burman, E., Hong, S.M., Yu, J., **Wang, Z.**, Mumovic, D., Shrubsole, C., Vermeer, D. and Davies, M., 2018. Towards a framework to evaluate the ‘total’ performance of buildings. *Building Services Engineering Research and Technology*, p.0143624418762662.

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