STUDENT MODELLING COMPETITION

Simulation, design and optimization of a nearly net zero carbon emission building

Building Simulation 2023
Briefing Document

Modelling competition panel (in alphabetic order)

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1. Background

As part of the Building Simulation Conference (https://bs2023.org/), IBPSA is organizing a student **modelling** competition. The aim is to facilitate wider participation in the conference and to provide a competitive forum for student members of the building simulation community. It is expected that several tutors of relevant courses in universities around the world will use this competition as part of their teaching material. This document contains all the information relating to the competition. Entries will be judged prior to the conference with an award being made at the conference in Shanghai in September 2023.

2. Tasks

For this year's competition, the aim of this exercise is to use computer simulation to **design and optimize a nearly net zero carbon emission building** given the constraints listed in the document. Participating teams are encouraged to use **active measures** (such as photovoltaic, battery storage, charging pile or ice storage) and **passive measures** (such as fluctuating room temperature, thermal storage in walls, controllable lighting and other demand side management) for carbon reduction.

To simplify, **the optimized content only includes the carbon emissions of buildings in the operation phase, mainly involving the carbon emissions of cooling, heating, lighting and plug loads. Only electric equipment is allowed in this building, that is, fuels such as natural gas are not applied in the building.**

- The building for analysis is the students' activity center of Tongji University in Jiading Campus in Shanghai, China. The site condition and building drawings are provided in the attached Appendix A. A more detailed file in dwg format will be available on the website;
- Only the energy consumption and carbon emissions of the tower part under the typical annual condition are studied, and the energy consumption of the podium part is not included in the analysis. However, the ventilation channels of the podium and tower can be used as passive ventilation paths;
- The typical year weather file can be downloaded from the Building Simulation conference website;
- Entrants are free to choose the design for all aspects of the building envelope, if these meet the listed constraints (see Appendix B);
- Dynamic carbon emission factor can be found in the Appendix E, which can be used to transfer the electricity consumption to carbon emissions;
- Both active and passive measures to reduce carbon emission from heating, cooling, lighting and plug loads during operation should be taken into consideration. Photovoltaic, battery storage, charging pile or ice storage is expected to be applied in the building. Roofs and elevations of towers and podiums are available for installation. Other measures to consider include fluctuating room temperature, thermal storage in walls, controllable lighting and other demand side management.

Based on the dynamic carbon emission factor in the Appendix E, entrants are

expected to assess the carbon emissions of the building during the operation, by means of appropriate models and metrics and to apply strategies to minimize carbon emission caused by cooling, heating, lighting and plug load, whilst providing comfortable conditions.
Entrants are free to propose the heating, cooling and mechanical ventilation systems, but must provide details of these in their report.
All entrants must use validated building performance simulation.

3. Provided inputs and constraints

Constraints must be followed precisely. Any deviation from any requirements (including, but not limited to, adjusting receptacle and other plug loads), unless explicitly mentioned below, will result in disqualification. The intention is to remove uncertainty with many project parameters so that the competitors can concentrate on a specific case on an equal playing field.

Weather

The data set of typical weather year (TMY) in Shanghai will be provided (sourced from Meteorological dataset for building thermal environment analysis in China). The weather files will be in the EPW format, which is an open comma-separated values file (delimited text file) and may be translated to other formats as needed.

Comfort conditions

All spaces are to be maintained between 18°C and 26°C when occupied. There are no requirements on unoccupied hours and humidity.

Geometry

Floor plans of the building showing room layout and dimensions as well as building sections are provided in Appendix A. These plans must be followed exactly and rooms may not be rearranged.

Ventilation

Ventilation rates are provided in Appendix C, however these may be ignored as a demand controlled ventilation system can ensure that the CO_2 will never rise above 1000ppm.

Dynamic carbon emission factors

Dynamic carbon emission factors for different seasons can be found in the Appendix E, which can be used to convert the hourly electricity consumption to hourly carbon emissions.

Additional inputs

The following additional constraints are provided in Appendix D.

- Internal heat gains and schedules (Internal heat gains and schedules of occupants and equipment are mandatory. If daylight controls as applied, internal heat gains and schedules of lighting can be adjusted but need to meet the required illumination levels)

- Illuminance levels – these can be used to reduce the prescriptive lighting energy by doing a lighting design calculation and daylight dependent control

4. Non-restricted inputs

Inputs that the design teams may decide to vary include:

- Shading
- Daylight controls
- Complete HVAC system (air-side, water-side, etc)
- Renewable energy
- Battery

5. Evaluation and judging criteria

- The key factors influencing the judges' decision will be accurate and intelligent use of building simulation and adequate use of performance metrics. It will not account for any site specific interventions outside of the building footprint.
- Entrants will be judged on the design feasibility, carbon emission performance and robustness of proposal to include all parameters and input, while providing a salient solution that is achievable.

Competition submissions can be either individual or group submissions. Following judging by an expert panel, two finalists will be identified. In case of group entries, a group leader should be nominated as corresponding person, and the total number of team members cannot exceed four (4).

Please note that the decision of the judges is final, and there will be no further discussion nor negotiations.

6. Deliverable Report

One (1) report containing the following sections:

a. Title page, including author(s) name(s), affiliation(s), and contact details

b. Executive Summary (maximum of 1 page)

c. Contents

d. Nomenclature

e. Introduction

f. Building and energy system design

1) Explanation of options considered and decision process(es)

g. **Modelling** methods employed

1) Explanation of **modelling** techniques used to evaluate CO_2 emissions, Energy Cost Measures and HVAC system selection

h. **Modelling** assumptions

i. Results

1) Ensure all graphs provided are legible and concise to support overall results.

2) Additional graphics can be included in Appendix.

j. Conclusions

k. References (if required)

l. Appendix (if required)

Note: The deliverable report should not exceed 20 pages excluding references and the annex section

7. Enrollment and notification of finalists

All entrants must be enrolled as students (PhD, MSc, BSc or equivalent) at the time of submission (i.e. April 28th 2023). Entrants must upload the following documents, as a proof of their 'student' status:

1) A bonafide letter on the university/institute letterhead from the supervisor or faculty-in-charge

2) Photocopy of the student ID provided by the university/institute

Entrants who fail to submit these documents will be disqualified. Please note that in the case of group entries, each member must submit these documents.

All entrants will participate in an online defence to determine finalists. The two finalists will be notified by June 1ST, 2023 and will receive free registration to BS2023 plus up to US $2000 (per group) in reimbursed travel expenses. The two finalists will be expected to attend the Building Simulation 2023 conference and to prepare a short presentation and produce a poster for display at BS2023. Poster requirements and travel/registration information for the finalists will be provided at that time. Based on the conference presentation and poster, an overall winner will be selected and announced at the conference.

8. Key dates

- February 1st, 2023: Notification of intent: all students who intend to submit will have to notify the BS modelling competition team via email: student@bs2023.org
- May 15th, 2023: Deadline submission: the requested report should be sent via email in PDF format to student@bs2023.org
- Around June 1st, 2023: Online defence
- June 15th, 2023: Two finalists informed
- September 4-6, 2023: BS2023 conference in Shanghai, China

9. Queries

If you require any further information, please contact us at the following e-mail: student@bs2023.org

Please use email for correspondence and try to make your question as concise as possible.

All questions and responses will be posted on the Student Competition section of the BS2023 website. Please check first that your query has not already been answered.

Thank you.

10. Submitting to other conferences

Groups and individuals intending to submit report and results to a different conference must acknowledge the IBPSA BS23 modelling competition in this paper.

Appendix A：Site and buildings

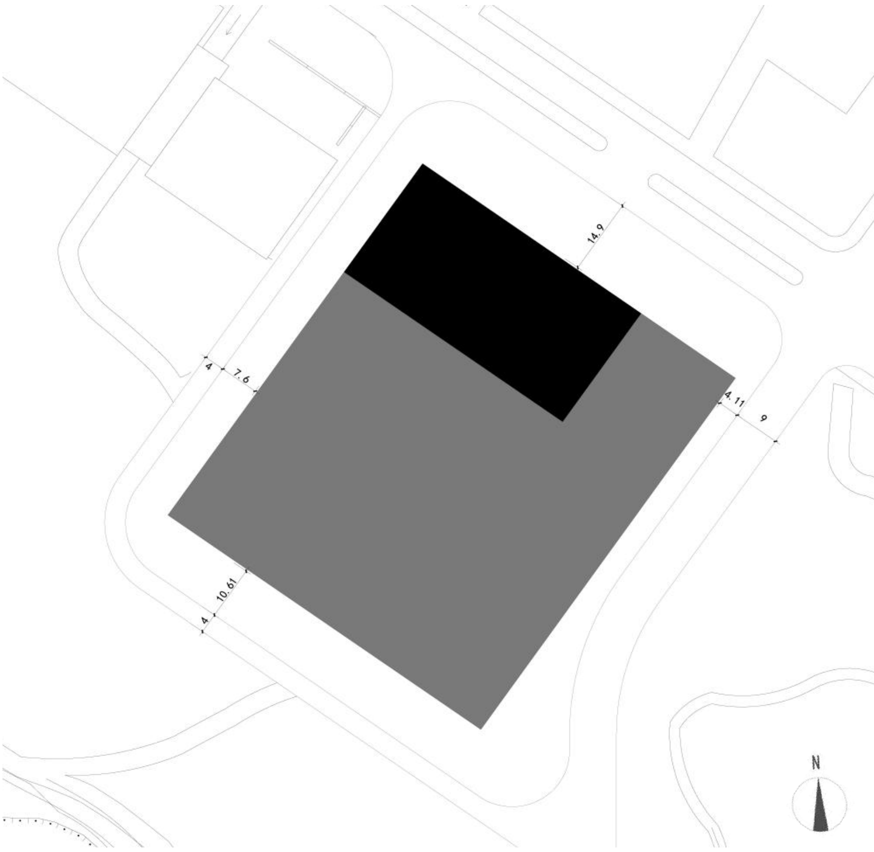


Figure 1 Site Plan. Building Footprint Area = 1326 m^2

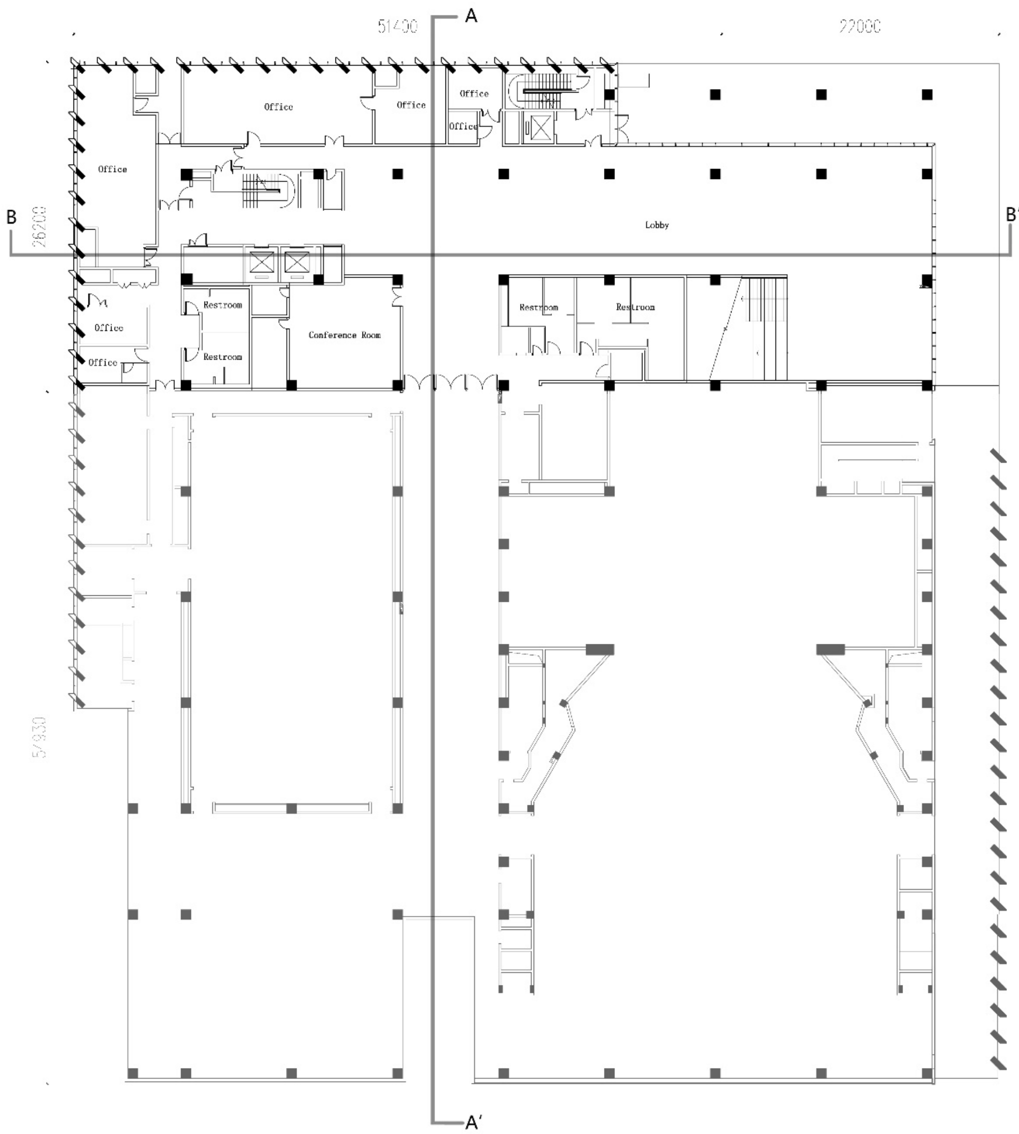


Figure 2 Ground Floor

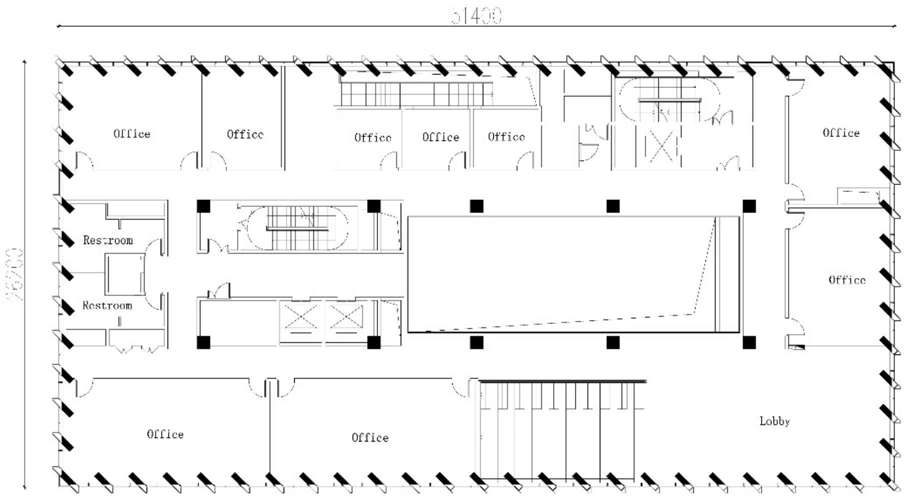


Figure 3 Typical Floor (Level 7)

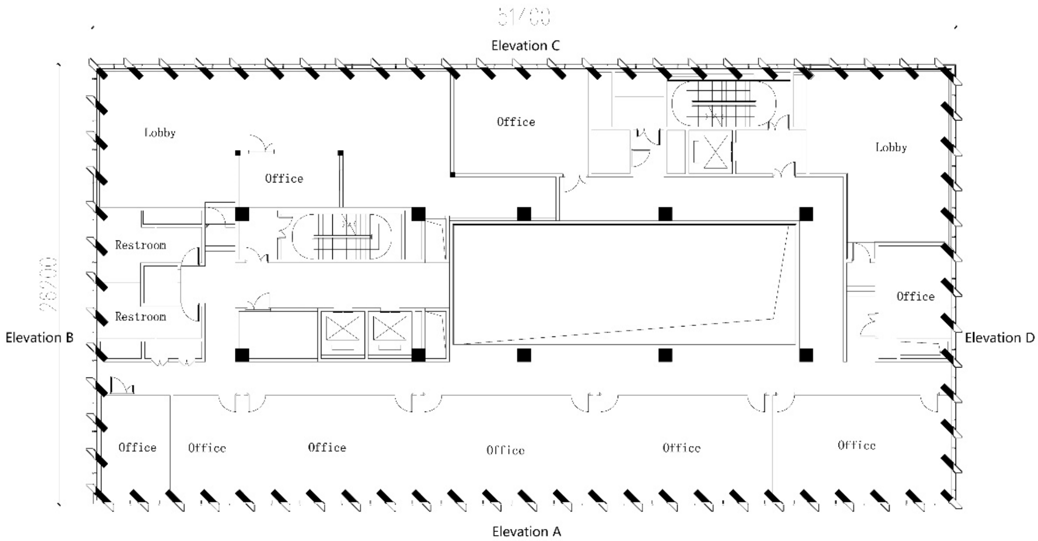


Figure 4 Top Floor

Window to wall Ratio (the number of each elevation refers to Figure 3 and 4)

Elevation	Window to Wall Ratio
Elevation A	0.76
Elevation B	0.76
Elevation C	0.76
Elevation D	0.76

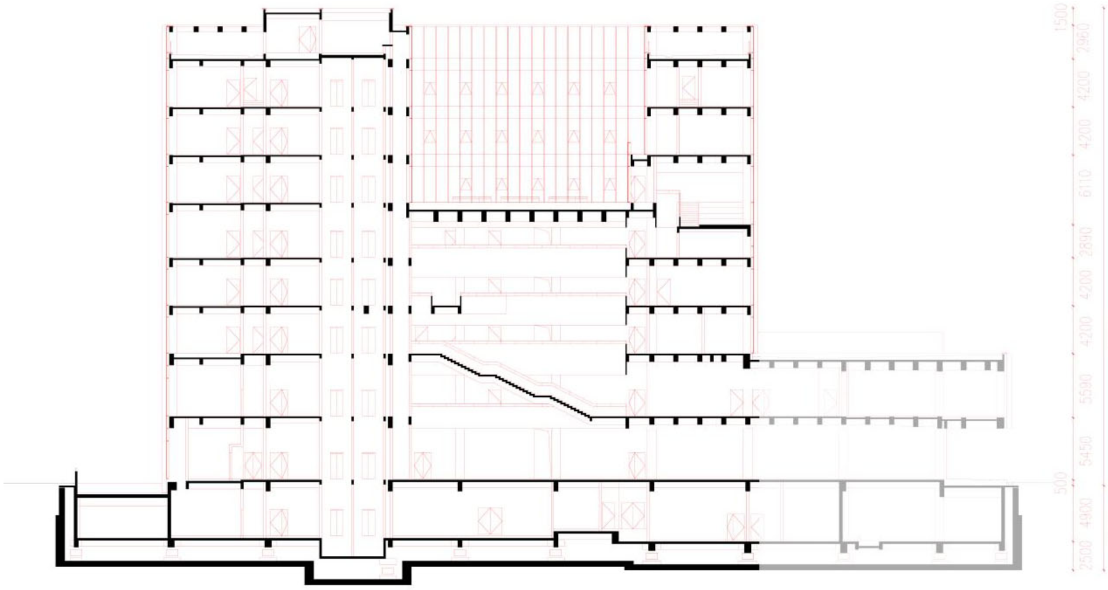


Figure 5 Section A-A′

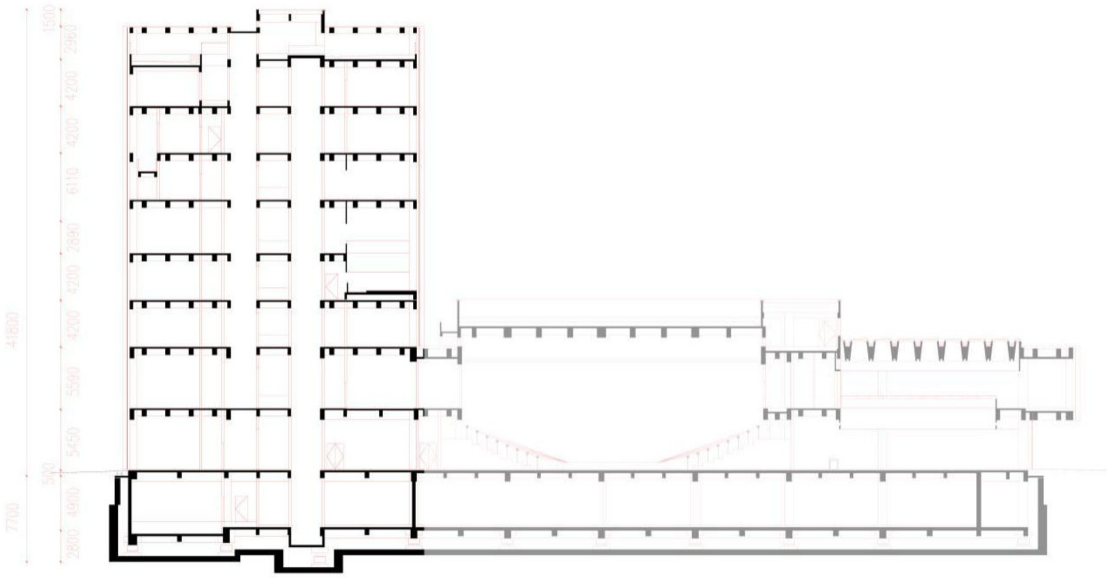


Figure 6 Section B-B′

Appendix B：Envelope components constraints

Referring to the Green Design Standard for Public Buildings in Shanghai (DGJ 08-2143-2021& DGJ 08-107-2015), the design of the building's envelope for this competition should be within the following constraints:

		Area constraints		**Conductivity constraints W/(m·K)**	**Shading factor SC （East, West, South/North）**
Transparent envelope	External windows	Window-to-wall ratio (WWR) for Single façade for each orientation	≤0.4	≤2.0	≤0.40/0.50
			>0.4 & ≤0.5	≤2.0	≤0.35/0.45
			>0.5 & ≤0.7	≤1.8	≤0.30/0.40
			>0.7	≤1.5	≤0.25/0.35
	Translucent Roof	Less than 20% of the total roof area		≤2.2	≤0.30
Non-transparent envelope	External walls			≤0.8	
	Roof			≤0.5	
Interior materials	Transparent door			<3.5	
	Non-transparent door			<2.5	
	Internal wall			≤2.0	
	Internal floor			≤2.0	

Recommended materials are as follows: (These materials are for reference only and may be substituted)

		Recommended materials and their properties	
		Name	**Conductivity W /(m·K)**
Transparent envelope	External windows	High transmittance Low-e+20Ar+5	1.6
		High transmittance Low-e+20Ar+5	1.6
	Translucent Roof	High transmittance Low-e+20Ar+5	1.6
Non-transparent envelope	External walls	Gypsum-based inorganic insulation mortar	0.2
	Roof	Foamed Cement Board	0.08
Interior materials	Transparent door	Lower light transmittance Low-e+20Ar+5	1.2
	None-transparent	Wood	0.15

	door		
	Internal wall	XPS	0.03
	Internal floor	XPS	0.03

Appendix C: Occupancy densities, Ventilation & Illumination requirements

	Assembly Hall, Multi-function Room, Conference Room	**Office**	**Lobby, Four-season hall, Over hall**	**Restroom, Lavatory**
Occupancy density PF (pers./m^2)	0.6	0.12	0.01	0.05
Ventilation requirement (occupancy period) (m^3/(h·person))	≥12	30	10	8 ACH of exhaust air
Minimum Room illumination (lux)	300	300	50	50

Appendix D: Internal Gains & Schedules

Assembly Hall, Multi-function Room, Conference Room

Name	Heat gains due to people(W/person)		Heat gains due to lighting(W/m²)	Heat gains due to equipment(W/m²)
	Sensible	Latent		
Heat gains	61.0	68.4	18.0	5.0

Hours	Occupancy ratio of people		Occupancy ratio of lighting		Occupancy ratio of equipment		Occupancy ratio of air conditioner	
	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0.5	0.4	0.5	0.4	0	0
8	0	0	1	0.4	1	0.4	0	0
9	1	0	1	0.67	1	0.67	1	0
10	1	0	1	0.67	1	0.67	1	0
11	1	0	1	0.67	1	0.67	1	0
12	0	0	1	0.67	1	0.67	0	0
13	0	0	1	0.67	1	0.67	0	0
14	1	0	1	0.67	1	0.67	1	0
15	1	0	1	0.67	1	0.67	1	0
16	1	0	1	0.67	1	0.67	1	0
17	0	0	1	0.67	1	0.67	0	0
18	0	0	1	0.4	1	0.4	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0

Office

Name	Heat gains due to people(W/person)		Heat gains due to lighting(W/m²)	Heat gains due to equipment(W/m²)
	Sensible	Latent		
Heat gains	61	68.4	4.5	200

Hours	Occupancy ratio of people		Occupancy ratio of lighting		Occupancy ratio of equipment		Occupancy ratio of air conditioner	
	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0.1	0	0.1	0	0.1	0	0.1	0
9	1	0	1	0	1	0	1	0
10	1	0	1	0	1	0	1	0
11	0.9	0	0.9	0	0.9	0	0.9	0
12	0.3	0	0.3	0	0.3	0	0.3	0
13	0.9	0	0.9	0	0.9	0	0.9	0
14	1	0	1	0	1	0	1	0
15	1	0	1	0	1	0	1	0
16	1	0	1	0	1	0	1	0
17	1	0	1	0	1	0	1	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0

Lobby, Four-season hall, Over hall

Name	Heat gains due to people(W/person)		Heat gains due to lighting(W/m^2)	Heat gains due to equipment(W/m^2)
	Sensible	Latent		
Heat gains	58	115.5	15	0

Hours	Occupancy ratio of people		Occupancy ratio of lighting		Occupancy ratio of equipment		Occupancy ratio of air conditioner	
	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0

3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	1	1	0	0	1	1
7	1	1	1	1	0	0	1	1
8	1	1	0.5	0.5	0	0	1	1
9	1	1	0.5	0.5	0	0	1	1
10	0.8	0.8	0.5	0.5	0	0	1	1
11	0.8	0.8	0.5	0.5	0	0	1	1
12	1	1	0.5	0.5	0	0	1	1
13	1	1	0.5	0.5	0	0	1	1
14	1	1	0.5	0.5	0	0	1	1
15	1	1	0.5	0.5	0	0	1	1
16	0.5	0.5	1	1	0	0	1	1
17	0.5	0.5	1	1	0	0	1	1
18	0.8	0.8	1	1	0	0	1	1
19	1	1	1	1	0	0	1	1
20	1	1	1	1	0	0	1	1
21	0.7	0.7	1	1	0	0	1	1
22	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0

Restroom, Lavatory

Name	Heat gains due to people(W/person)		Heat gains due to lighting(W/m^2)	Heat gains due to equipment(W/m^2)
	Sensible	Latent		
Heat gains	58	42.6	2	0

Hours	**Occupancy ratio of people**		**Occupancy ratio of lighting**		**Occupancy ratio of equipment**		**Occupancy ratio of air conditioner**	
	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday	Monday-Friday	Saturday-Sunday
0	0	0	0.5	0.5	0	0	0	0
1	0	0	0.5	0.5	0	0	0	0
2	0	0	0.5	0.5	0	0	0	0
3	0	0	0.5	0.5	0	0	0	0
4	0	0	0.5	0.5	0	0	0	0
5	0	0	0.5	0.5	0	0	0	0
6	0	0	0.5	0.5	0	0	0	0
7	0.5	0.5	0.5	0.5	0	0	0	0
8	0.8	0.8	0.5	0.5	0	0	0	0
9	1	1	0.2	0.2	0	0	0	0
10	1	1	0.2	0.2	0	0	0	0

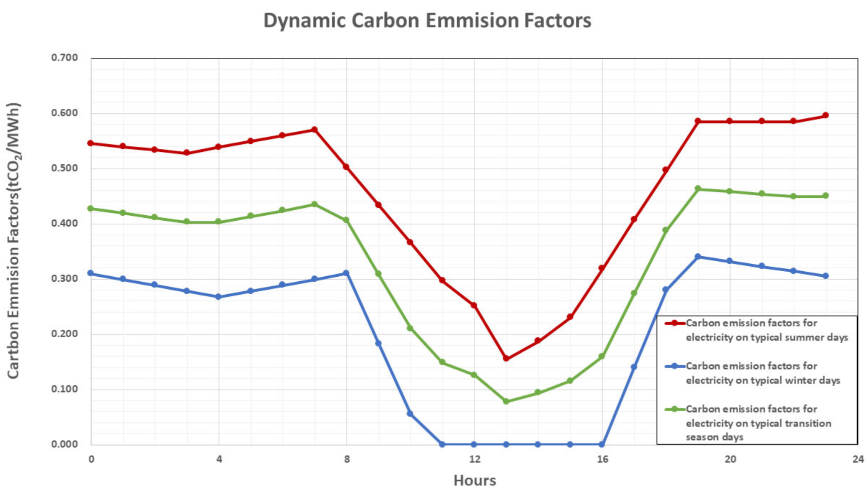
11	1	1	0.2	0.2	0	0	0	0
12	1	1	0.2	0.2	0	0	0	0
13	1	1	0.2	0.2	0	0	0	0
14	1	1	0.2	0.2	0	0	0	0
15	1	1	0.2	0.2	0	0	0	0
16	0.5	0.5	0.2	0.2	0	0	0	0
17	0.5	0.5	0.2	0.2	0	0	0	0
18	0.8	0.8	1	1	0	0	0	0
19	1	1	1	1	0	0	0	0
20	1	1	1	1	0	0	0	0
21	0.7	0.7	1	1	0	0	0	0
22	0	0	1	1	0	0	0	0
23	0	0	0	0	0	0	0	0

Appendix E: Dynamic carbon emission factors

	$EF_{grid, OM\ Simple,y}$(tCO_2/MWh)
Eastern China Regional Power Grid	0.7921

$$\text{Dynamic carbon emission factor} = \frac{\text{Total instantaneous carbon emissions}}{\text{Total electricity of the whole grid}}$$

Hours	**Carbon emission factors for electricity (tCO_2/MWh)**			**Hours**	**Carbon emission factors for electricity (tCO_2/MWh)**		
	Typical summer days	**Typical winter days**	**Typical spring and autumn days**		**Typical summer days**	**Typical winter days**	**Typical spring and autumn days**
0	0.545	0.310	0.427	**12**	0.251	0.000	0.125
1	0.539	0.299	0.419	**13**	0.155	0.000	0.077
2	0.534	0.288	0.411	**14**	0.188	0.000	0.094
3	0.528	0.278	0.403	**15**	0.230	0.000	0.115
4	0.538	0.267	0.403	**16**	0.319	0.000	0.159
5	0.549	0.278	0.413	**17**	0.408	0.140	0.274
6	0.559	0.289	0.424	**18**	0.496	0.280	0.388
7	0.570	0.299	0.435	**19**	0.585	0.340	0.463
8	0.502	0.310	0.406	**20**	0.585	0.331	0.458
9	0.433	0.183	0.308	**21**	0.585	0.323	0.454
10	0.365	0.055	0.210	**22**	0.585	0.314	0.449
11	0.297	0.000	0.148	**23**	0.595	0.305	0.450



Note:

Summer: July to September;

Winter: January to February, December;

Transition season: March to June, October to November