Human Centric Lighting in an office building

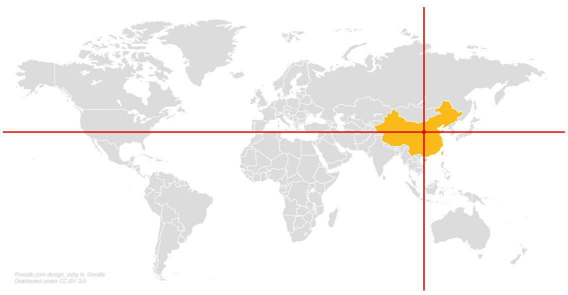
Improving the light environment of an office building with different technological solution

In this office building, a lighting retrofit with Human Centric Lighting (HCL) system is provided. The HCL can fully change brightness and colour temperature. Based on ZPLC (Zero Power Line Communications) technology, it takes less than three months to complete the replacement and commissioning, without changing the original power line. After renovation, the luminous environment was greatly improved, while achieving more than 60% energy saving compared to the previous lighting system..

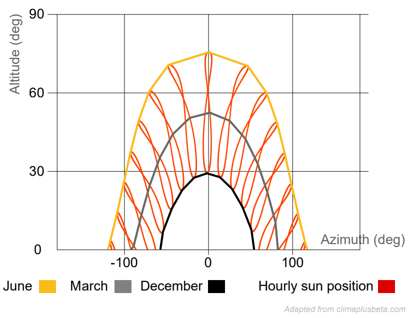
Figure 1. The Xining Central Sub-branch of the People's Bank of China.

The project

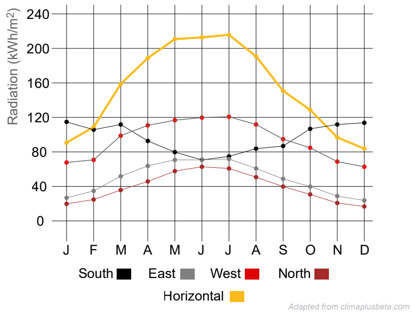
The project is in Xining, the largest city on the Qinghai-Tibet Plateau in China, with an altitude of 2261 meters. It belongs to the typical plateau alpine cold temperature climate, light climate zone II. The Xining Central Sub-branch of the People's Bank of China is an agency of the People's Bank of China. Its main responsibility is to implement the monetary policy formulated by the head office, maintain financial stability, and provide financial services in the Qinghai area. The office building of the People's Bank of China Xining Center Branch is a typical comprehensive office building for financial business. Built in the 1990s, it was once a landmark building in Xining City, Qinghai Province. It has 20 floors and a building area of about 18,000 square meters. The walls are all decorated with natural warm-colour marble, and the decoration style is solemn. After years of operation and use, the lighting facilities are gradually aging, the lighting is seriously not up to standard, and the energy consumption is high. In 2019, the building underwent a lighting upgrade and renovation. The lighting renovation project is also included in the Chinese "13th Five-Year" national key research and development



Location: Xining, Qinghai, China
36.62,101.72



Sun path for
Xining, Qinghai, China



Global horizontal and vertical radiation for
Xining, Qinghai, China

IEA SHC Task 61 Subtask D
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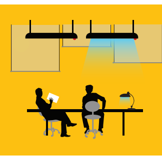

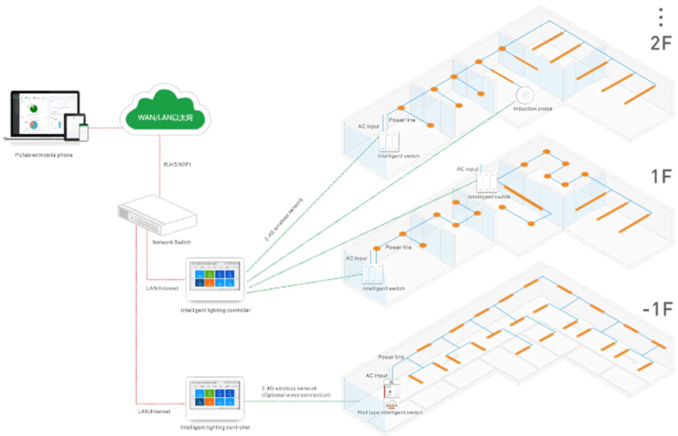

Figure 2. Conceptual scheme of the networked lighting control system with data collection in the IoT based cloud platform.

plan for green buildings and key special technology demonstration projects for building industrialization.

The new building lighting system consists of a completely peer-to-peer distributed network. The system network uses the gateway group as the subnet node. Each subnet can connect to 256 (32× 8) device, the system network can accommodate up to 64 subnets, and the maximum capacity of the system is 16384 (256×64) devices. The system uses distributed software processing technology to realize the functions of centralized control and management of the lighting system, data storage, and data input and output.

Different lighting strategies were adopted in the project. First, based on the design concept of healthy lighting, all light sources in this project adopt a dimmable and colour tunable LED lighting system, which can dynamically adjust the luminous flux from 0% to 100%, and the colour temperature range is from 2700 K to 6000K . According to current knowledge on healthy lighting technology, all of the office spaces are provided with a dynamic adjustment of intensity and colour of lighting during the day. This is expected to follow the natural daily path of sunlight, thus respecting the human biological rhythm. The dynamic lighting is designed by taking the vertical illuminance needs at the human eye position.

Then, according to the characteristics of public areas and office areas, different energy-saving operation strategies have been set up. In areas such as halls, corridors, and el-

Figure 3. The monitoring team during the field measurements.

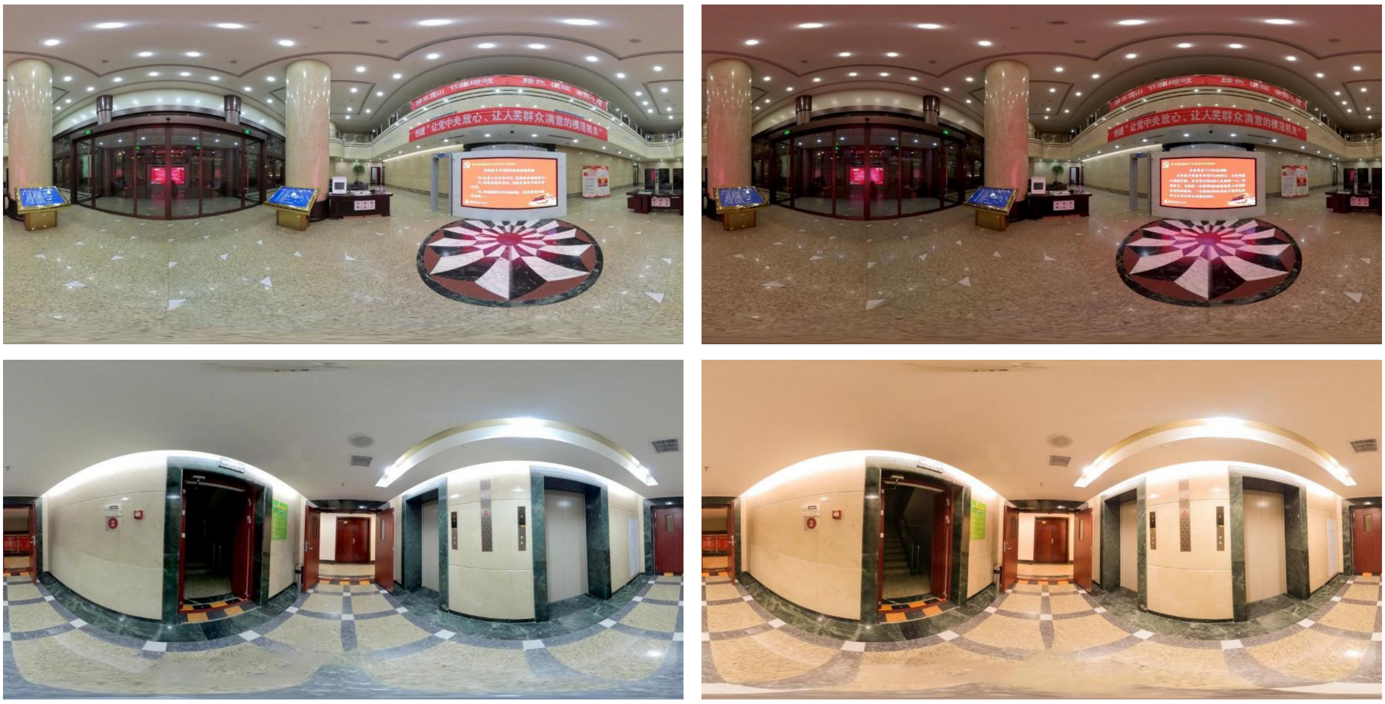

Figure 4. Details of two of the common areas in the building. The extreme CCT settings are shown in picture.

evators, in accordance with the characteristics of the flow of people and usage requirements of government offices, time sequence control is adopted during working days to achieve dynamic adjustment of luminous flux, but also correlated colour temperature. At the same time, the areas are also equipped with occupancy sensing control for turning off the lights when the space is unoccupied. The meeting rooms in the office area adopt scene control. Lamps are grouped, and the control scene can be adjusted at any time to meet the needs of various lighting modes. The office has set two control modes. The first is health-based: the lighting system follows a HCL schedule, which combines the working habits of personnel and the needs of healthy lighting to realize the dynamic adjustment of light colour. The second is energy saving based: lighting is adjusted according to occupancy and natural lighting, in a combination of daylight harvesting and absence sensing.

Finally, Intelligent lighting cloud platform control based on the Internet of Things. The lighting operation data of this project is connected to the cloud platform through the Internet of Things. The cloud platform can use big data analysis methods and adapt and improve the control strategy algorithms based on such data. If remote control is required, selected users with administration permissions can log in to the web page to control the brightness, colour temperature, and scenes of lighting of all areas.

Monitoring

Offices, conference rooms, halls, and corridors were selected on site for testing the light environment. The test items included the illumination of working plane, uniformity ratio of illuminance, colour rendering index, correlated colour temperature, stroboscopic effect and unified glare rating. The light environment parameters under different lighting modes in offices, meeting rooms, halls, corridors, and other areas were tested.

Energy

The project replaced and installed 4878 light sources and 409 control devices, and the total installed power of the system was 83534 W. The project system has energy consumption measurement and monitoring capabilities, which can monitor lighting energy consumption data in

Table 1. Energy use for lighting for the whole building after retrofit compared with the benchamark value.

Electricity use	Total energy use (kWh/y	LENI (kWh/m2y)
Calculated value (kWh)	81 000	8.1
Reference value (kWh)	212 000	21.2
Energy saving	61%	

Table 2. Evaluation of the luminous environment (electric lighting). R = Reference value or benchmar, M = Measured value.

Evaluation index		Office	Meeting room	Hall	Corridor
Illuminance on working plane (lux)	R	300/500	300/750	200	50/100
	M	475	322/762	228	54
Uniformity ratio U_0 (%)	R	0.6	0.6	0.6	0.4/0.6
	M	0.8	0.9/0.7	0.8	0.8
Colour Rendering Index R9	R	80	80	80	80
	M	84	85	84	83
Correlated Colour Temperature Tcp (K)	R	> 0	> 0	-	-
	M	9	2.3	-	-
Stroboscopic ratio (%)	R	≤ 3	≤ 3	-	-
	M	2	1	-	-
Unified glare rating URG	R	19	19	-	25
	M	8	19	-	18

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Table 3. Measured lighting characteristics for the lighting system in an exemplary office. Results are shown for the seven available settings.

Parameter		Mode 1	Mode 4	Mode 7	Mode 5	Mode 2	Mode 6	Mode 3
Light output ratio		100%	100%	100%	80%	60%	30%	20%
Output Power (kW)		0.225	0.225	0.225	0.180	0.135	0.0675	0.045
Use time /h		2	2	2	1	0.5	1.5	0
Illumination of working plane	Average value (lux)	615	610	604	475	356	193	127
	Uniformity ratio U_0	0.7	0.8	0.8	0.8	0.8	0.87	0.8
Vertical illuminance (lux)		287	—	—	—	—	—	—
Luminance (cd/m^2)	Panel Light	3340	—	—	—	1842	—	623
	Wall	120	—	—	—	73	—	26
	Ceiling	64	—	—	—	39	—	15
Luminance ratio (excluding lamps)		1.9	—	—	—	1.9	—	1.7
Correlated Colour Temperature (K)		5394	5132	4637	4642	4289	3451	2939
Colour Rendering Index Ra		82	83	84	84	84.3	86	83.3

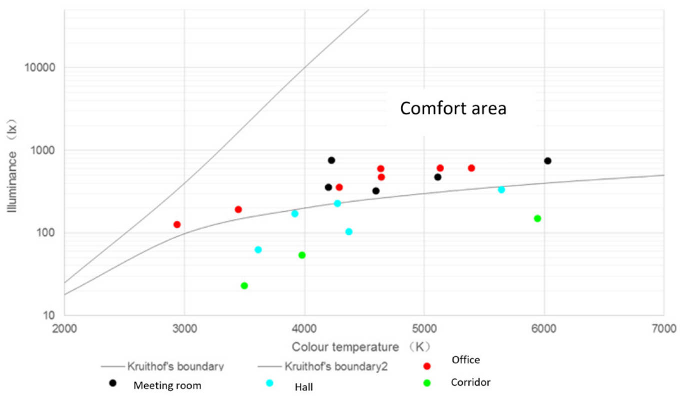

Figure 5. Kruithof diagram with illuminace and CCT coordinates for different lighting settings in the monitored rooms.

real time. After comparison, the total energy saving rate of the project lighting has reached 61%.

Photometry

The test results of on-site light environment are as follows.

All values resulted significantly better than the standard requirements. The light environment parameters under different lighting modes in offices, meeting rooms, halls, corridors, and other areas were tested. In Table 3, those for an exemplary office as shown.

Illuminance and colour temperature for the different modes were plotted on the Kruithof curve. The Kruithof curve propose a so-called comfort area for specific combination of illuminance and colour temperature. Although the Kruithof curve is currently criticized in the scientific lighting community, it remains a widespread tool in lighting design practice.

Circadian potential

At time of writing, no specific monitoring was conducted for the circadian potential of the project. However, since the lighting design is expressly based on HCL principles, it is very much likely that the electric lighting provide the right lighting stimuli at the right time as suggested by current knowledge in the field.

User perspective

Informal chats with building managers and employees suggest that lighting has been significantly improved after renovation. At the same time, the project has achieved an energy saving rate of more than 60%.

Lessons learned

This retrofit project combined principles of HCL with energy saving strategies. Depending on space and needs, HCL or energy saving were favored. The dual goals allowed to design an "healthy" lighting and still save an impressive amount of energy. The implementation of a cloud platform collecting lighting and occupancy data provides an additional instrument to further reduce energy demand, while keeping high the occupants' satisfaction.

Further information

www.heuvan.com

Acknowledgements

Financial support: 13rd five-year plan research project: Study on Standards and Integrated Demonstration for Luminous Environment Promotion of Public Buildings
Special thanks to the Xining Central Sub-branch of the People's Bank of China and HEUVAN (CHONGQING) SCI-TECH CO., LTD.