

Energy, Water, and Land resources consumption of the Public Building: A Case of the People's Bank of China

Tong Xu ^{a,b}, Longyu Shi ^{a,*}

^a Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, China, lyshi@iue.ac.cn

^b Centre for Environment, Energy and Natural Resource Governance, Department of Land Economy, University of Cambridge Cambridge, United Kingdom, tx224@cam.ac.uk

ABSTRACT

Urbanization is one of the major events in the 21st century has caused rapid growth in the global construction area, which resulted in high consumption of building resources and long term environmental impacts. Analyzing the resource consumption of public buildings and identifying the key factors that affect the consumption of building resources is therefore important for the development of targeted policies. In this paper, we analyzed each branch of the People's Bank of China (PBC) based on energy, water, and land resource consumption as well as the structure of energy consumption. Based on resource-consumption indicators, we divided 31 provincial administrative into four resources consumption levels; of these, 65% were in the middle or low resource consumption levels. Medium-sized institutions had the highest energy consumption level and more balanced energy consumption structure. Energy consumption per capita, water consumption, and utilization rate of small-sized institutions were low. To reduce resource consumption by public institutions, construction of large-sized institutions should be limited.

The annual EF of output or waste generation was given by:

$$EF_p = \frac{P}{Y_N} \times YF \times EQF \times IYF$$

The EF of time series data was:

$$EF = \sum \frac{P_{N,j,j}}{Y_{N,j,j}} \times YF_{N,j,j} \times EQF_{N,j,j} \times IYF_{N,j,j}$$

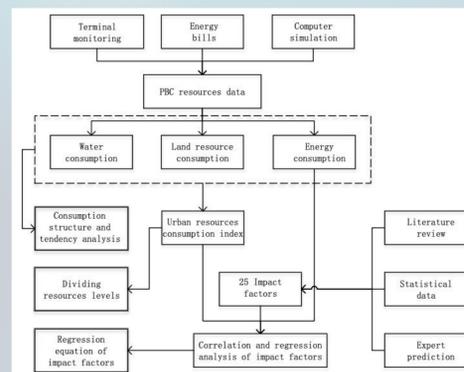


Fig. 1. Framework for resource consumption analysis and impact factors selection

METHODS

The People's Bank of China (PBC) was established in December 1948 to issue the national currency and manage state finances. Branch offices can be categorized as small-sized (area $\leq 5,000$ square meters), medium-sized (area between 5,000 square meters and 20,000 square meters), and large-sized (area $> 20,000$ square meters) public buildings.

UWCI and ULCI were calculated by dividing the annual comprehensive water consumption and comprehensive building area by the energy consumption of the institutions. The URCI calculation is shown in Eq. (1):

$$URCI = \frac{1}{3}(UWCI + ULCI + UECl)$$

The urban human development index (UHDI) consists of the education index (EI), the life expectancy index (LEI), and the income index (IIN), as follows:

$$UPDI = \frac{1}{6}(UAP_{SO_2} + UAP_{NO_2} + UWP_{COD} + UWP_{NH_4} + USW_{SW} + USW_{HW})$$

Where E_j is the coefficient of years of education for a population with j culture level, P_j is a population with education level j , and P is the total population

$$UHDI = \frac{1}{3}(EI + LEI + IIN)$$

$$EI = \frac{1}{2} \left(\sum \frac{E_j P_j}{P} + ER_{P_6} \times 6 + ER_{P_3} \times 3 + ER_{P_0} \times 0 + ER_1 \times 4 \right)$$

RESULTS

A. Consumption of Energy and Water Resources by PBC Branches of Various Size

The energy consumption per capita of large-sized institutions was higher than that of medium-sized and small-sized institutions (Fig 2).

The average water consumption per unit area was 1.6, 1.2, and 1.1 m^3/m^2 , respectively (Fig 3).

B. Major energy consumption sources of PBC

In 2011, the PBC's main energy sources included raw coal, electric energy, gasoline, natural gas, and diesel, representing 37%, 29%, 21%, 7%, and 5% total energy consumption, respectively (Fig. 4).

Figure 5 shows that the consumption of electricity, natural gas, and diesel was lowest in small-sized institutions, although the proportion of gasoline consumption was the highest (27.9%).

C. Water resource, energy, and land resource consumption for provincial-level administrative regions

UWCI significantly varied among provinces (Fig. 6); values for Shanghai, Jiangsu, and Tianjin were relatively low (0.011–0.020), those for Fujian, Jilin, and Shanxi were intermediate (0.041–0.045).

D. Resource Consumption and Classification of Each Provincial-Level Administrative Region

Grade I ($URCI < 0.070$, mean 0.065), included five administrative regions where PBC branches had relatively low resource consumption: Xinjiang, Inner Mongolia, Shanghai, Yunnan, and Ningxia. Grade II ($0.070 \leq URCI < 0.080$, mean 0.076) (Fig. 7).

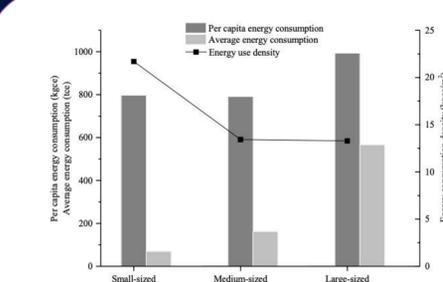


Fig. 2. Energy consumption of different-sized branches of People's Bank of China

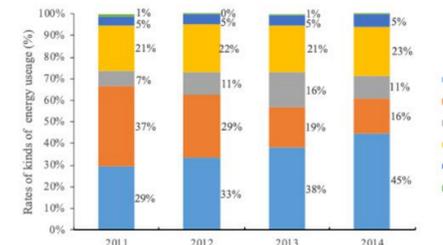


Fig. 4. People's Bank of China energy consumption structure, 2011–2014

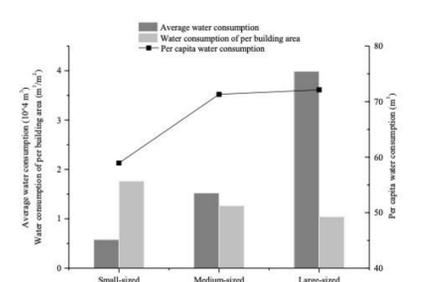


Fig. 3. Water consumption of different-sized branches of People's Bank of China

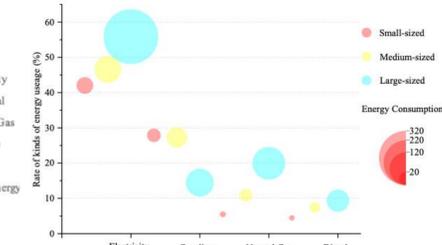


Fig. 5. Proportions of main energy sources consumed by the People's Bank of China according to branch size, 2014

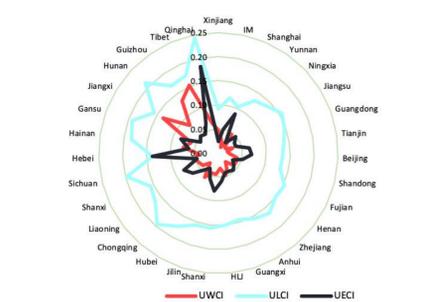


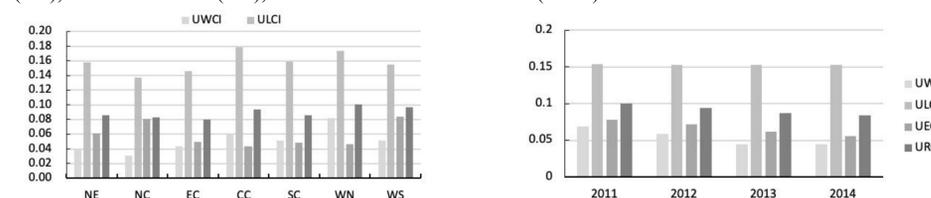
Fig. 6. Consumption of water, energy, and land resources by the level of People's Bank of China at the provincial level, 2014



Fig. 7. Distribution of resource consumption among 31 provincial-administrative regions of the People's Bank of China, 2014.

E. Consumption level of PBC in various regions

The UWCI value of Northwest China (NWC) was highest (0.082) (Fig. 8), followed by Central China (CC), and North China (NC), which had the smallest UWCI (0.031).



G. Correlation Analysis of PBC Energy and Resource Consumption

Eight indices (Table 1) were significantly correlated with EC ($P < 0.01$): FA, PEC, NV, WC, GDP, YEP, PCPB, and CR. The index with the highest correlation coefficient was FA; PCPB and CR were negatively correlated with EC. Multicollinearity was identified among independent variables; a stepwise linear regression was conducted to obtain the following regression equation:

$$EC = 0.114 + 0.309 \times PEC - 0.148 \times CR \quad (R^2=0.619)$$

The strongest positive correlation was between WC and URCI (0.484), and the strongest negative correlation was between PGDP and URCI ($P < 0.01$). Stepwise regression was used to obtain the following regression equation.

$$URCI = 0.087 - 0.023 \times FA + 0.048 \times WC - 0.021 \times PCPB \quad (R^2=0.437)$$

TABLE 1. CORRELATION BETWEEN THE PEOPLE'S BANK OF CHINA'S ENERGY CONSUMPTION AND EACH INDEX

Index	EC	FA	PEC	NV	WC	GDP	YEP	PCPB	CR
EC	1	0.771**	0.753**	0.691**	0.61**	0.328*	0.547**	-0.54**	-0.312*
FA		1	0.895**	0.878**	0.716**	0.584**	0.87**	-0.577**	0.115
PEC			1	0.854**	0.726**	0.566**	0.792**	-0.975**	-0.011
NV				1	0.665**	0.541**	0.84**	-0.49*	0.107
WC					1	0.199	0.588**	-0.327*	0.106
GDP						1	0.775**	0.006	0.14
YEP							1	-0.472*	0.317*
PCPB								1	-0.128
CR									1

CONCLUSION

The energy consumption level of medium-sized institutions was higher than that of small- and large-sized institutions; water consumption was high in medium-sized and large-sized institutions. From 2011 to 2014, the total energy consumption of all PBC buildings decreased. Electricity replaced coal as the main energy source in 2012. The resource consumption index decreased in China as a whole; resource consumption in Northwest and Southwest China was higher than that in the eastern and northern regions. Population and climatic region significantly affected energy consumption; building area, water consumption, and the number of public books per capita significantly impacted the resource consumption index.

Abbreviation	Full name	Abbreviation	Full name
URCI	Urban resources consumption index	PCDI	Per capita disposable income
UWCI	Urban water consumption index	PEI	Pollutant emission index
ULCI	Urban land resources consumption index	EI	Education index
UECI	Urban energy consumption index	PCPB	Number of public books per capita
FA	Floor area	NHP	Number of health-care personnel per 1,000 resident
PEC	Population of energy consumption	NPV	Number of people with public vehicles per 10,000 resident
NV	Number of vehicles	CR	Climate region
WC	Water consumption	UPDI	Urban pollutant discharge index
HDI	Human development index	UAPI	Urban air pollution emission index
EF	Ecological footprint	UWPI	Urban water pollution emission index
YEP	Population at the end of the year	USPI	Urban solid waste discharge index
GDP	Gross domestic product	EUI	Energy use intensity
PGDP	Per capita gross domestic product	EC	Energy consumption
PCCE	Per capita consumption expenditure	IPCC	Intergovernmental Panel on Climate Change
PBC	People's Bank of China	COD	Chemical oxygen demand
SW	Solid waste	HW	Household waste transportation
LEI	Life expectancy index	IIN	Income index