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

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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 based on energy, water, and land resource consumption as well as the structure of energy consumption. Based on resource-consumption indicators, we divided 31provincial 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.

Keywords—building energy consumption, consumption of building resources, resource consumption index, sustainable development

I. INTRODUCTION

Buildings are the key areas for human activity; they also consume significant resources result in series environmental impacts and thus become the hot-spot for sustainability issues. In 2010, the fifth IPCC report (IPCC AR5) reported that global building consumption accounted for 32% of terminal energy consumption and 51% of electricity consumption, which represent 19% of global greenhouse gas emissions and 33% of black carbon emissions (IPCC, 2015; Huang et al., 2013). China as the world's second-most prolific consumer of construction resources after the United States and the largest producer of carbon emissions is developing rapidly, with a significant amount of infrastructure being built (BECRC, 2016; Liu, 2015). The Ministry of Housing and Urban–Rural Development of China estimates that during 2005–2020, about 30 billion square meters of new buildings will be constructed, which account for approximately 50% of the global area of new construction during the same period (Huang et al., 2013; Wang et al., 2015; Berardi, 2016). This rapid infrastructure development obstructed China's goals for sustainable development. It is therefore important to enhance the utilization efficiency of building resources and identify the key factors affecting resource consumption for China's buildings.

According to use, construction can be categorized into civil buildings, industrial buildings and agricultural buildings. Civil buildings can be further categorized as public and residential buildings. Public building includes offices, cultural and educational buildings, health buildings, commercial buildings, transportation buildings, financial buildings, and landscape architecture.

The size of the public building can reflect the level of public services in the region, the regional level of economic development, and the regional characteristics of social activities (Olonscheck et al., 2011). The United States ranks first in public building area per capita, with 24 m2, followed by Canada, Britain, Germany, and Italy (IEA, 2015). In 2014, the total construction area in China was 56.1 billion m2, of which public building area account for （only？）19%; the public building area per capita was only 8 m2, lower than that of most developed countries (BECRC, 2016). Among the types of public buildings existing, office buildings account for the highest proportion, about 3.7 billion square meters, followed by integrated shopping areas (2.3 billion square meters). The area devoted to medical, educational, cultural, and integrated services needs to be increased.

Public building facilities are important suppliers of resource and energy services. However, due to limited data on public building construction, the energy and resource consumption of the public building in most countries is incomprehensive. Public building energy consumption accounts for roughly 2%–6% of China's total energy consumption. For example, energy consumption by national public institutions accounts for 2.3%, 1.7%, and 4% of total energy consumption in Germany, France and the United States. In 2014, the total energy consumption of buildings in China used 819 million tons of standard coal, representing nearly 20% of the country's total energy consumption. The energy consumption of urban residential buildings, rural residential buildings, and public buildings (excluding heating in northern areas) was 23%, 25%, and 29%, respectively. Energy consumption of public buildings per unit area in China has grown from 16.8kgce/m2 in 2001 to 21.9kgce/m2 in 2014; over the same period, energy intensity increased by about 30% (Olonscheck et al., 2011). Increasing demands for energy consumption in public buildings strongly contributes to energy intensity due to volume and structure, especially for recently built buildings and large-sized centralized systems such as air conditioning, lighting, elevators, and ventilation. In most countries, energy consumption per unit area of large public buildings is 10–20 times than that of residential buildings, and total energy intensity is significantly higher than that of ordinary buildings. Therefore, the effective control of public building energy and resource consumption in China is important for sustainable development.

In this study, we analyzed 1). energy consumption structure and overall consumption level of the People's Bank of China (PBC). 2). evaluated the effects of architecture, energy consumption structure, population, economy, public resources, and environment. The objectives were to determine the main factors that affect energy consumption and provide a theoretical basis for sustainable development and public building energy management.

II. Methods

A. Data collection

First, The PBC was established in December 1948 to issue the national currency and manage state finances. In 1995, the National People's Congress passed the Law of the People's Republic of China on the People's Bank of China for the first establishment of the PBC as a central bank which belongs to the state organs. It became a public institution and directly accepted a financial allocation. Branches of the bank were therefore distributed throughout the country, and the construction activities encompass many characteristics. Branch offices can be categorized as small-sized (area ⩽ 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. They can also be categorized according to their energy intensity and as government/commercial office buildings. As medium-intensity public buildings, PBC branches have higher energy intensity than schools, hotels, stadiums, and other low-energy public buildings, but their energy intensity is lower compared with shopping malls, hospitals, and other high-energy public buildings.

This study focus on energy and resource consumption of the public building by taking 365 branches of the PBC in 2011–2014 as a case study. Data on energy consumption and institutional scale were obtained from PBC headquarters and analysis of terminal monitoring, energy bills, and computer simulations.

B. Energy and Resource Consumption Assessment Indices

The According to the sustainable development goals of the 13th Five-Year Plan (e.g., "strengthening the management of binding indicators, implementing the dual control actions such as energy and water consumption, construction land, and so on"), the 2015 China Urban Sustainability Report, and other research papers (Zhu et al., 2014; Zhu et al., 2015; Yang et al., 2017), the urban resources consumption index (URCI) (Appendix A) was composed based on three major items: the urban water consumption index (UWCI), urban land resource consumption index (ULCI), and urban energy consumption index (UECI). Here we examined 25 factors influencing resource consumption from the aspects of architecture, energy consumption structure, population, economy, public resources, environment, and climate. Specific indicators include floor area (FA), population of energy consumption (PEC), number of vehicles (NV), water consumption (WC), human development index (HDI), ecological footprint (EF), annual mean temperature, population at the end of the year (YEP), urban population density, gross domestic product (GDP), per capita gross domestic product (PGDP), per capita consumption expenditure (PCCE), per capita disposable income (PCDI), per capita road area, parks and other green areas, green coverage rate of built-up areas, pollutant emission index (PEI), education index (EI), number of universities, the average number of students per 100,000 residents, number of public books per capita (PCPB), number of publication distribution outlets, number of health-care personnel per 1,000 resident (NHP), number of people with public vehicles per 10,000 resident (NPV), and climate region (CR) (Appendix B) (Liu 2009; Liu et al. 2013; Zhan et al. 2015). The relevant indices and indicators were calculated as follows.

UECI was measured based on per capita consumption of standard coal by dividing the annual combined energy consumption of each bank branch by the number of energy users. Raw coal, natural gas, gasoline, diesel oil, and electricity were converted into standard coal equivalents in accordance with the General Rules for the Calculation of Comprehensive Energy Consumption (National Standard of the People's Republic of China, GB/T 2589–2008) (Appendix C). This value was converted to standard coal power, which is often used in two ways. The first is the coal consumption method for power generation, which considers the amount of standard coal required to produce 1 kWh of power. However, power generation efficiency could be affected by specific power plant characteristics and other factors. The second is the electric equivalent method, which uses 1 kWh of power, theoretical heat value of 3,600 kJ, and 1 kg of standard coal to arrive at a theoretical caloric value of 29,307 kJ by direct conversion. Energy loss during the process of coal-to-electricity conversion is not needed to be considered in this case, by which 1 kWh of electricity equals 0.1229 kg of standard coal based on the electro-thermal equivalent method.

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):

$$\mathrm{URCI}=\frac{1}{3}(\mathrm{UWCI}+\mathrm{ULCI}+\mathrm{UECI}) \quad (1)$$

C. Calculation of other relevant indicators

During the process of urban production and consumption, atmospheric, water, and solid waste pollutants are produced. Pollutant levels are influenced by consumption levels and patterns, technological levels and structure, environmental protection investments, and other factors. The urban pollutant discharge index (UPDI) used in the correlation analysis consists of the urban air pollution emission index (UAPI), urban water pollution emission index (UWPI), and urban solid waste discharge index (USWI). UWPI was calculated based on the amount of ammonia nitrogen (N-NH4) and chemical oxygen demand (COD) of polluted water. UAPI was calculated based on industrial sulfur dioxide (SO2) and nitrogen oxide (NOX) concentrations. USWI was calculated based on industrial solid waste (SW) and household waste transportation (HW). These six pollution indicators for per capita emissions were calculated before data processing. The UPDI equation is as equation (2):

$$\mathrm{UPDI}=\frac{1}{6}\left(\mathrm{UAP}_{\mathrm{SO_2}}+\mathrm{UAP}_{\mathrm{NO_X}}+\mathrm{UWP}_{\mathrm{COD}}+\mathrm{UWP}_{\mathrm{N\text{-}NH_4}}+\mathrm{USW}_{\mathrm{SW}}+\mathrm{USW}_{\mathrm{HW}}\right)$$

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

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

$$\mathrm{EI}=\frac{1}{2}\left(\sum\frac{\mathrm{E}_j\mathrm{P}_j}{\mathrm{P}}+\mathrm{ER}_{\mathrm{PS}}\times 6+\mathrm{ER}_{\mathrm{JHS}}\times 3+\mathrm{ER}_{\mathrm{SS}}\times 3+\mathrm{ER}_{\mathrm{U}}\times 4\right) \quad (4)$$

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. ER_{PS}, ER_{JHS}, ER_{SS}, and ER_{U} represent the net enrollment ratios of primary, secondary, high school, and university, respectively. Net enrollment rate was difficult to quantify, as was the actual gross enrollment rate. The main sources of data included the Statistical Communique on National Economic and Social Development, Statistical Communique on Educational Development, and Twelfth Five-Year Plan on Educational Development.

IIN was measured based on purchasing power parity-converted PGDP, and LEI was measured based on life expectancy per capita (Zhu et al., 2015). Data was acquired from the China City Statistical Yearbook 2015, Social Development Twelfth Five-Year Plan, and provincial and municipal statistical yearbooks.

The calculation method and content of the EF were mainly based on the NFA 2014 guidance book developed by Borucke (Borucke et al., 2012; Elias, 2014).

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

$$\mathrm{EF}_P=\frac{\mathrm{P}}{\mathrm{Y}_N}\times\mathrm{YF}\times\mathrm{EQF}\times\mathrm{IYF} \quad (5)$$

The EF of time series data was:

$$\mathrm{EF}=\sum\frac{\mathrm{P}_{N,i,j}}{\mathrm{Y}_{N,i,j}}\times\mathrm{YF}_{N,i,j}\times\mathrm{EQF}_{W,i,j}\times\mathrm{IYF}_{i,j} \quad (6)$$

Where EP_P is the ecological footprint of the product or waste, P is the amount of output or waste, Y_N is the average output of a country, YF is the yield factor for a given land type, EQF is the equilibrium factor for a given land type, and IYF represents the inter-temporal yield factor for a given land type.

D. Data Linearization Standardization

Due to variations in units of measurement, comprehensive evaluation cannot be directly used for calculation and comparison. Standardized pre-processing indicators were thus evaluated to form a comprehensive index. Common linear normalization methods include the range method, extreme value method, normalization method, and efficiency coefficient method. In this study, the extreme value method—which has monotonicity, difference invariance, and scale-independent advantages—was used. The formula is as follows:

$$y'=\frac{x}{x^*} \quad (7)$$

Where x^* has a maximum acceptable value of $x_{\max}$, minimum value of $x_{\min}$, and mean of $\bar{x}$. In this experiment, we used $x_{\max}$.

The theoretical framework for analyzing resource consumption and impact factors is shown in Fig. 1.

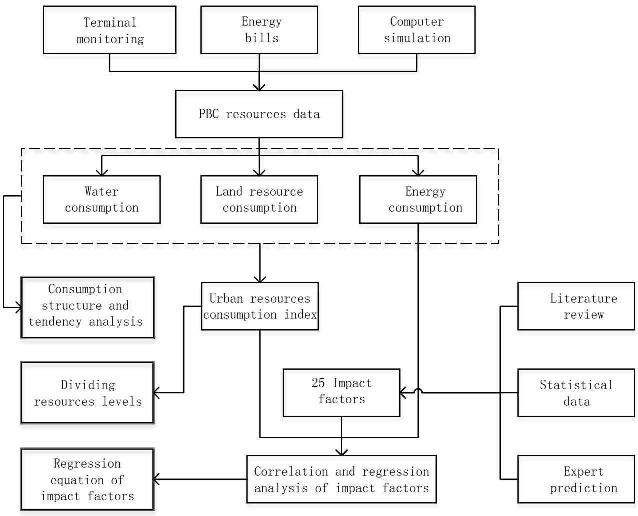

Fig. 1. Framework for resource consumption analysis and impact factors selection

III. RESULTS

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

Based on Chinese architectural design standards, the sample was divided into three groups according to the area: small-sized, medium-sized, and large-sized (Shi et al., 2015). The sample included 16 small-sized institutions, 284 medium-sized institutions, and 65 large-sized institutions. The average FA of the small, medium, and large-sized institutions was 3,543 square meters, 12,518 square meters, and 37,860 square meters, respectively. The average area of large-sized institutions was 10.7 times larger than that of small-sized institutions and three times that of medium-sized institutions.

Small-sized institutions accounted for 4.4% of the sample, their area represented 6.6% of total the area, and their energy consumption represented 8.7% of total energy consumption. Medium-sized institutions represented 77.8% of total institutions, their area represented 23.2% of total construction area, and their energy consumption represented 20.4% of total consumption. Energy consumption by large-sized institutions represented 70.9% of total energy consumption, and their area represented 17.8% of the total construction area. The energy consumption per capita of large-sized institutions was higher than that of medium-sized and small-sized institutions (Fig. 2). Total energy consumption of large-sized institutions was significantly higher than that of medium-sized and small-sized institutions (P <0.05). Energy use intensity (EUI) refers to the input required to produce a unit of output and is usually measured in terms of energy per unit area. The EUI of small-sized institutions was 19.7 kgce/m^2, which was higher than that of medium-sized (13 kgce/m^2) and large-sized institutions (15 kgce/m^2).

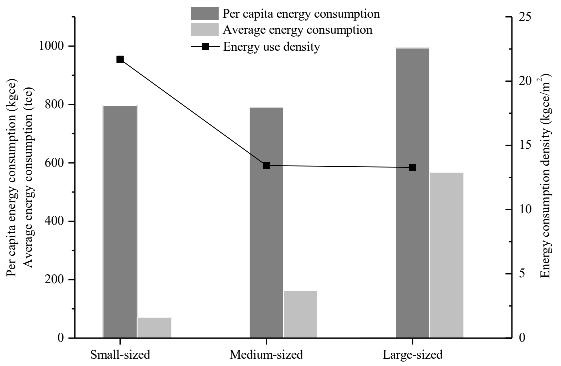

Fig. 2. Energy consumption of different-sized branches of People's Bank of China

As shown in Fig. 3, the average annual consumption of water for small, medium, and large-sized institutions was 0.6 × 10^4, 1.5 × 10^4, and 4 × 10^{4}m^3, respectively. The average water consumption per unit area was 1.6, 1.2, and 1.1 m^3/m^2, respectively. Small-sized institutions had the highest water consumption per unit area and per capita. Large-sized institutions had the lowest water consumption per unit area, and the water consumption per capita of large branches was higher than that of medium-sized institutions.

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); other energy sources represented only 1%. From 2011 to 2014, the proportion of raw coal consumption decreased to 16%, less than half of its proportion in 2011. The proportion of electricity increased from 29% in 2011 to 45% in 2014. Gasoline and diesel consumption remained relatively stable. The proportion of natural gas fluctuated, rising to 16% from 2011–2013, decreasing to 11% in 2014, and dropping sharply in 2012–2014 (representing less than 0.2% of energy consumption).

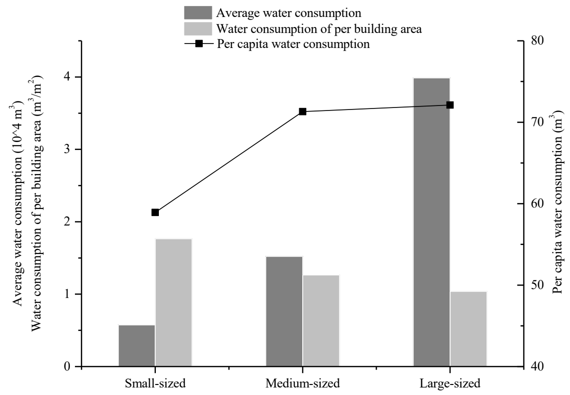

Fig. 3. Water consumption of different-sized branches of People's Bank of China

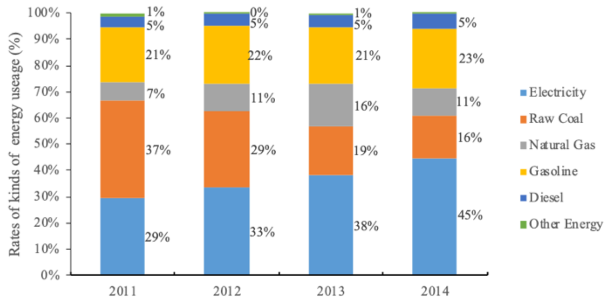

Fig. 4. People's Bank of China energy consumption structure, 2011–2014

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%). Medium-sized institutions displayed a more balanced energy consumption structure with contributions from various sources and a high proportion of gasoline consumption (27.2%). In large-sized institutions, electricity, natural gas, and diesel fuel consumption accounted for the highest proportion of energy consumption, whereas gasoline consumption accounted for the lowest proportion.

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

To analyze resource consumption in different regions, statistical data for the PBC was processed as described in Sections 2.3 and 2.4. 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), and those of Tibet, Jiangxi, and Guizhou were highest (0.131–0.155). Energy consumption and land resource consumption by the PBC in 31 provinces of China were analyzed using radar charts in 2014. The UECI values of Xinjiang, Yunnan, and Fujian provinces were lower than 0.035; values for Hunan, Shandong, and Jilin were higher (0.051–0.056) than those of Qinghai, Hebei, and Shanghai (0.085–0.185). Compared with UWCI and UECI, ULCI fluctuated little among provinces and municipalities. Lowest values (0.090–0.110) were found in Xinjiang, Shanghai, Shaanxi, and other regions; values in Fujian, Anhui, and Jiangsu provinces were moderate (0.153–0.157), and those in Qinghai, Hunan, and Sichuan were highest (0.195–0.250).

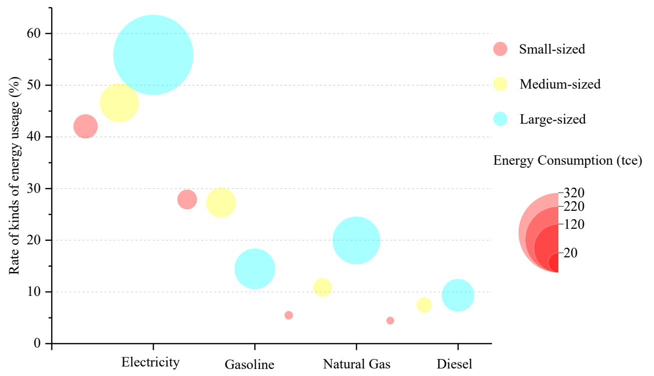

Fig. 5. Proportions of main energy sources consumed by the People's Bank of China according to branch size, 2014

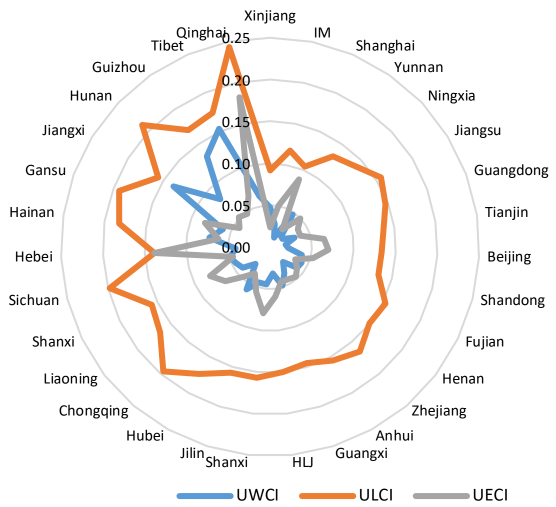

Fig. 6. Consumption of water, energy, and land resources by the People's Bank of China at the provincial level, 2014

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

The URCI values of the PBC in provincial administrative regions were graded and visualized using ArcGIS 10.0 (Fig. 7). The 31 provincial-level administrative divisions were divided into four levels (Zhu et al., 2015). 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 ≤ URCI < 0.080, mean 0.076) included 10 provincial administrative regions: Jiangsu, Guangdong, Tianjin, Beijing, Shandong, Fujian, Henan, Zhejiang, Anhui, and Guangxi. The URCI values of these regions were below average levels. Grade III (0.080 ≤ URCI <0.110, mean 0.093) included Heilongjiang, Shanxi, Jilin, and Hubei. Grade IV had relatively high URCI values (0.110–0.170, mean 0.125) and included the provincial administrative regions of Gansu, Jiangxi, Hunan, Guizhou, Tibet, and Qinghai. Among these levels, 65% of total provincial-level administrative regions were categorized as grades II and III, representing 77% of the total population and 89% of total GDP. Therefore, the level of PBC's resource consumption is mainly medium to low.

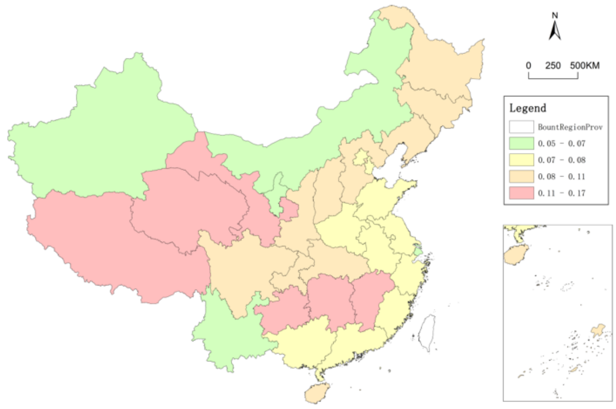

Fig. 7. Distribution of resource consumption among 31 provincial-level administrative regions of the People's Bank of China, 2014.

E. *Consumption level of PBC in various regions*

The 31 provincial-level administrative regions (excluding Taiwan, Hong Kong, and Macao) were divided into seven geographical regions (Appendix D). 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). ULCI was high in NWC, second only to CC (0.178), and NC had the lowest value (0.137). UECI was highest in Southwest China (SWC) (0.084), with value was slightly higher than that of NC. CC had the lowest value (0.043). URCI was the highest in NWC (0.101), second highest in SWC, third highest in CC, and lowest in NC and East China (0.083 and 0.800, respectively).

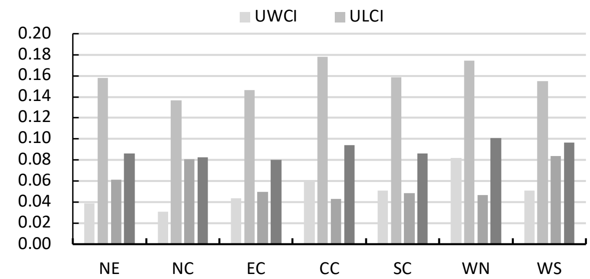

Fig. 8. Regional average consumption of resources by the People's Bank of China, 2014

F. *Resource consumption by PBC*

As seen in Fig. 9, UWCI decreased from 0.069 in 2011 to 0.045 in 2013, and stabilized around 0.0443 in 2014. ULCI did not significantly change during 2011–2014; the index for each consecutive year was 0.154, 0.152, 0.153, and 0.153. UECI decreased annually from 0.078 in 2011 to 0.056 in 2014. URCI also declined from 0.100 to 0.084 over this time period. The consumption of various types of resources (except ULCI) decreased during 2013–2014. There were no significant differences in consumption among types of resources during 2011–2013 ($P > 0.05$).

G. *Correlation Analysis of PBC Energy and Resource Consumption*

Our analysis relied on data obtained from China's Statistical Yearbook, the China City Statistical Yearbook, the China Environment Statistical Yearbook, and the Statistical Bulletin of Educational Development Statistics published by provinces and cities. It also incorporated energy consumption (EC) and resource consumption indicators. The data showed a non-normal distribution. Spearman's correlation analysis was conducted using SPSS 22.0 (IBM) software. 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:

$$EC = 0.114 + 0.309 \times PEC - 0.148 \times CR \quad (R^2{=}0.619) \tag{8}$$

There were significant correlations between URCI and eight indices (Table 2), including PGDP, EF, PCCE, PCDI, NHP, PCPB, NPV, and WC. 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.

$$URCI = 0.087 - 0.023 \times FA + 0.048 \times WC - 0.021 \times PCPB \quad (\text{R2=0.437}) \tag{9}$$

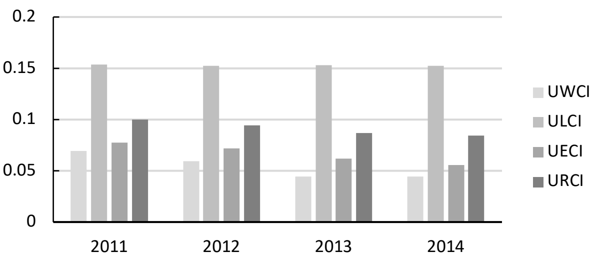

Fig. 9. Consumption of various types of resources by the People's Bank of China, 2011–2014

TABLE I. 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*	0547**	-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**	-0575**	-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

Note: ** indicates P <0.01, and * indicates P <0.05

IV. DISCUSSION

The average energy consumption and per capita energy consumption of large-sized institutions were higher than those of small and medium-sized institutions (Fig. 2). The reason could be that large buildings usually have a large floor area and require more energy to maintain basic operations (lighting, air conditioning, equipment, etc.). Server rooms in large-sized institutions are typically in operation 24/7 and use large amounts of power that produce significant heat emissions and high demand for air conditioning. Large-sized institutions therefore have much higher energy intensity than small and medium-sized institutions.

TABLE II. CORRELATION BETWEEN THE URCI OF THE PEOPLE'S BANK OF CHINA AND EACH INDEX

Index	URCI	PGDP	EF	PCCE	PCDI	NHP	PCPB	NPV	WC
URCI	1	-0.551**	-0.535**	-0.498*	-0.453*	-0.332*	-0.509**	-0.366*	0.484**
PGDP		1	0.958**	0.958**	0.932**	0.649**	0.731**	0.547**	-0.6**
EF			1	0.967**	0.925**	0.639**	0.748**	0.51**	-0.65**
PCCE				1	0.969**	0.555**	0.709**	0.561**	-0.613**
PCDI					1	0.547**	0.673**	0.489**	-0.578**
NHP						1	0.589**	0.346**	-0.329*
PCPB							1	0.34*	-0.719**
NPV								1	-0.35*
WC									1

Note: ** indicates P <0.01, and * indicates P <0.05

Based on energy consumption data in the United States, China, and Europe, the proportion of heating, hot water, cooling, and lighting in residential buildings, shopping malls, and other public buildings accounts for nearly 70% of total energy consumption. According to PBC energy consumption data for 2014, electricity was the highest energy source, representing 45% of total energy consumption, which was consistent with data collected from other sources. The proportion of electricity consumption in large-sized institutions was significantly higher than that of small and medium-sized institutions (Fig. 5). In medium-sized institutions, EUI (13.4 kgce/m^2) was lowest and energy consumption per capita (776.6 kgce) was lower than that of large-sized institutions (1031.3 kgce), but slightly higher than that of small-sized institutions (684.6 kgce). Medium-sized institutions had the highest energy consumption level among all institutions, which is in accordance with Wei (2009). This finding provides guidance for planning the size of public buildings. In small-sized institutions, water consumption per unit area was highest and water consumption per capita was lowest. Large-sized institutions had the lowest water consumption per unit area and the highest water consumption per capita.

Raw coal is the main fuel source for urban construction in China (Li, 2016). In 2011, coal consumption accounted for 37% of PBC's total energy consumption. From 2011 to 2014, electricity has gradually replaced coal as the principal source of energy. Although the proportion of gasoline consumption increased during that same period, total consumption decreased from 40.753 million liters to 28.462 million liters. Gasoline is mainly used for vehicle fuel and heating. From 2011 to 2014, the total number of vehicles decreased by 6.5%. As a result of heating and electric refrigeration, the consumption of gasoline and raw coal has decreased. Increased electricity consumption is caused by high-power office equipment, central air conditioning, lighting, etc. The proportion of gasoline consumption in small- and medium-sized institutions was high, probably due to the higher proportion of vehicles per capita compared with large-sized institutions. The proportion of natural gas consumption in large-sized institutions was high, probably due to central air-conditioning and heating.

We analyzed the factors influencing energy and resource consumption from the aspects of architecture, energy consumption structure, population, economy, public resources, environment, climate, etc., and eliminated the need for a multicollinearity index; our results are consistent with other reports (Chen et al., 2013; Han et al., 2015; Yin et al., 2015; Ye et al., 2016). Olonscheck et al. studied climatic conditions, building area, building energy efficiency, heating systems, etc., and identified climatic conditions and building energy efficiency as main reasons for decreased energy consumption (Olonscheck et al., 2011). Shen et al. (2016) affirmed the importance of implementing policies for promoting building energy efficiency (Shen et al, 2016). The Energy Conservation Law of the People's Republic of China (revised in 2008) and the Twelfth Five-Year Plan of the National Economic and Social Development promoted public energy saving and emission reduction regulations, and provided guidelines for implementing these objectives within PBC institutions. The short-term outcome of the Plan has been effective; in the long term, more energy efficient machinery, devices, and technologies should be introduced to decrease energy consumption (Zhu et al., 2016; Liu and Lin, 2017).

The consumption of land resources by the PBC stabilized during 2011–2014, indicating the no large-scale expansion of sub-branches during this period. Demolition, water resources, and energy consumption declined annually; overall resource consumption also declined. Consumption of water, energy, and land resources were highest in northwest and southwest regions of the country, whereas consumption in eastern and northern regions was lower. Many economic indicators may be related to resource consumption, including consumption expenditure per capita, disposable income per capita, and GDP per capita, but these economic indicators may be more important in eastern and western regions. Building area, water consumption, and the number of public books per capita strongly impacted resource consumption. The first two indicators have been analyzed and discussed by many scholars, but the number of public books per capita has been rarely mentioned. The R2 values for energy consumption and resource consumption regressions were 0.619 and 0.437, respectively, indicating that some secondary factors were not accounted for; these may be related to energy and resource management, personal qualities of employees, and behavioral issues. It would be beneficial to conduct further examination of such factors.

V. Conclusion

Sustainable development is a global problem that must be solved, especially in light of China's rapid development. The rapid increase in building resource consumption runs counter to the goals of sustainable development. Resource consumption by public institutions has attracted much attention. In this paper, we examined the energy, water, land, and other resource consumption of 365 PBC branches. 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. According to the resource consumption index, the 31 provincial administrative regions were divided into 4 levels. Grades II and III represented 65% of the total provincial administrative regions, 77% of the total population, and 89% of the total GDP; therefore, the level of resources consumption of PBC branches is medium or low. 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. To reduce resource consumption by public institutions, reduced growth of large public institutions with high energy consumption is suggested. This can be done by regulating the scale of new public buildings. In addition, the consumption of construction resources should not exceed that of former public institutions. The level of resource management and energy saving awareness should be improved, and data on energy consumption should be increased.

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