

Exploration on development mode of material and energy circulating metabolism on university campus:a case study of Chang'an campus of Northwest Polytechnical University

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Abstract. Every university campus usually bears the living consumption of materials and energy for thousands of people, and the linear metabolism aggravates the waste of materials and energy, and worsens the environmental pressure. However, the university campus can provide the additional site for the cycle facilities of the material and energy because of its abundant occupied land and low building density. Hence, the Chang'an campus of northwest polytechnic university will be studied as a typical case, and the development mode of material and energy circulating metabolism will be explored on the basis of the perspective of architecture and the focus point of material and energy circulating metabolism. The findings in this study will provide a new insight into developing the ecological mode of colleges and universities, thus propose a new solution to the ecological crisis.

1 Definition of campus circulating metabolism and analysis of life system elements

Because of more than 25 million of students from over 2000 colleges and universities in China,^[1] thus every university campus usually bears the living consumption of materials and energy for thousands of people. Furthermore, the linear metabolism aggravates the waste of materials and energy, and worsens the environmental pressure. It is significant to reduce the consumption of materials and energy on university campus under the popular trend of ecological development as the national will. The ecological development mode of colleges and universities will be explored to reduce the input of material and energy on university campus, on the basis of architecture perspective, the entry point of material and energy circulating metabolism and the link of cycle infrastructure, thus a new solution is put forward in the face of ecological crisis.

College campus, especially the new construction, is generally a relatively insulated system with distinct boundary, which features comprehensive functions of study, work, living, leisure. Due to the different specialties in various colleges, plenty of differences are observed in the consumption of material and energy, but living and leisure systems are relatively similar and replicated. Hence, the living system will be chosen as the research object in this study, with a case of Chang'an campus of Northwest Polytechnical University. The data in this paper is calculated by years.

2 Definition of campus circulating metabolism and analysis of life system elements

Campus circulating metabolism: Via recycling technology, the circulation of material and the flow of energy in campus is optimized to reduce the energy consumption, thus proposing a new saving circulation system of material and energy, and achieving the ecological development of campus. Campus living system, as opposite to the teaching system, meets the basic requirements of water and power supply, cooking and heating for whole students and staff.

- (1) Materials input: water, food and nutrients
- (2) Energy input: electricity and fuel

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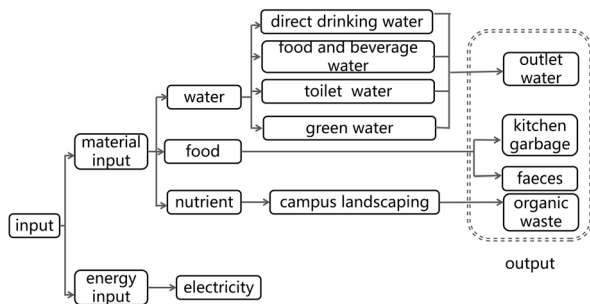


Fig. 1. Metabolism map of material and energy on Chang'an campus

3 Construction status of Chang'an campus of Northwest Polytechnical University

Chang'an campus, with 3,900 acres of area, 2.5 kilometers wide average of about 1.2 km, consists of the east (900 acres) and west regions (3,000 acres). The construction area is more than 730,000 m², covering an area of 198,000 m² and with a plot ratio of 0.4. There are 23,000 teachers and students living in the campus. The sewage treatment center, gas pressure regulating station, boiler room substation and other main supporting facilities are built in the east region. 120 acres of Qixiang lake, 50 acres of Qizhen lake and 85 acres of green landscape could be found in the campus.

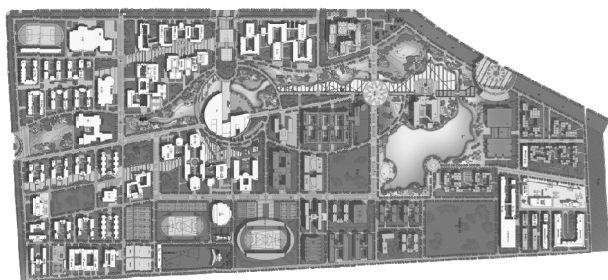


Fig. 2. Plan of Chang'an campus

4 Reconstruction of Chang'an campus

4.1 Material flow

Water: The input of water includes drinking, cooking, washing water and so on. Averaged person consume 108.95L of water in one day, in accordance to the 'Standard Domestic Water Consumption for Urban Residents in China' (GB/T 50331-2002). The total of 2300 staffs and students in Chang'an campus are estimated to discharge water with a rate of 2500 m³/d. However, the constructed wetland treatment system can effectively deal with the domestic wastewater, owing to numerous merits of large buffer capacity, good treatment efficiency, simple process, low investment and operation cost, and beautiful landscape. The clean of 1 m³ wastewater needs 10-50 m² of artificial wetland, according to the practical capacity of artificial wetlands in dealing with wastewater. The artificial wetlands,

transformed from 20 acres of qixiang lake and 50 acres of qizhen lake, can completely meet the treatment of campus domestic wastewater. After the treatment, the water will be used for the flushing, landscaping irrigation, cleaning, and so on, which can not only lower down the input of water resources and the discharge of wastewater, but also beautifies campus environment via artificial wetlands.



Fig.3. Qizhen lake



Fig.4. Qixiang lake

Rainwater collection: The collection and utilization of rainwater can not only effectively alleviate the current shortage of urban water resources, but also regulate rainwater via ground infiltration and water store, thus reducing the waterlogging and adjusting the climate^[2]. Herein, roof rainwater, with low pollution, large amount and easily collection, can be collected for greening, car washing, road pouring. The yearly precipitation of Xian is 604.1mm, and more than 90% of rainwater can be gathered. Due to 198161.65 m² of roof area on Chang'an campus, around 72000 m³ of rainwater, calculated from the formula of rainwater collection, can be collected annually to reduce the input of irrigation water. Rainwater collection formula:

$$Q = \Psi \alpha \beta A (H * 10^{-3}) \quad (1)$$

Where Q is referred as the available rainfall; Ψ , referred as the runoff coefficient, is set as 0.9; α is referred as the seasonal reduction factor; β , referred as the initial abandonment coefficient, is 0.86 in Xian. A is referred as the horizontal projected area of roof (m²), H is referred as the average precipitation (mm)^[3].

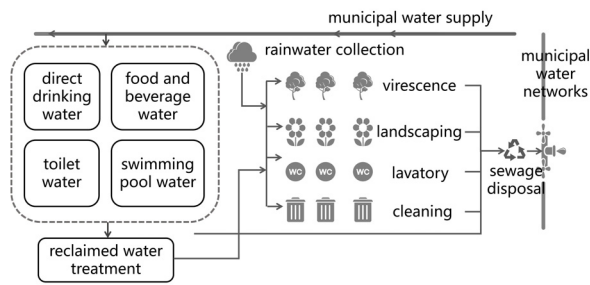


Fig. 5. The chart of water circulating metabolism

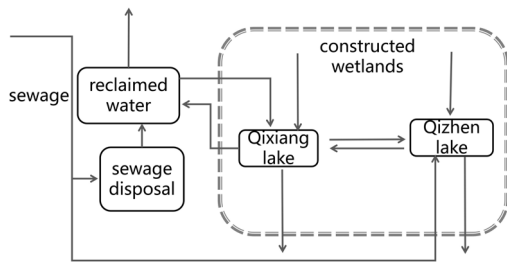


Fig. 6. The scheme of constructed wetland circulation

Food: Because average person produces around 0.96 kg/d of garbage every day^[4]. Considering 60% of kitchen waste and 280 d of school time in one year, around 3710 t of kitchen waste is annually produced in Chang'an campus. The vegetable waste anaerobic fermentation biogas digester, with the volume of 1500m³ and designed size of 40 m×20 m×1.9 m, can completely dispose the kitchen waste. The biogas production from anaerobic fermentation of kitchen waste can reach 0.6338 m³/kg, and 2.35 million m³ of biogas and 5220 t of marsh fertilizer will be produced from the fermentation of kitchen waste from Chang'an campus yearly, in which biogas can be utilized in cooking and saving fuel, marsh fertilizer is used for the campus greening and fertilizing, thus reducing the fertilizer input.

Nutrients: Average person will discharge around 0.2 Kg of daily feces, and 23000 people in the Chang'an campus are estimated to let out 138 t of excrement and urine during 180 d in one year. By constructing biogas fermentation pool and installing ceramic solar panels to keep the normal work of biogas fermentation pool in winter via warming, 220000 m³ of biogas and 138 t of marsh fertilizer will be produced annually, calculated by the biogas fermentation rate.

4.2 Energy flow

The average energy consumption per capita in colleges and universities is 4 times than that of the national average during the same period, in accordance with the statistical results of 45 colleges and universities in 2005^[5]. Therefore, it is of a great significance to construct a new energy or renewable resource infrastructure by utilizing campus site resources, thus reducing the energy input and benefiting for the campus ecological construction.

Electricity: The universities are basically supplied from the state grid, and few electricity from the clean and renewable energy is used in campus. As a renewable

and clean energy, solar energy has been widely used in the energy conservation, in which the solar photovoltaic power takes a crucial role. According to the '13th Five-year Plan for the Solar Energy Development' issued by the national energy administration at the end of 2016, more than 110 million kilowatts of solar power will be achieved at the end of 2020, indicating the rapid expansion of solar power in the future. Because of the vast area of building in the campus, the roof of teaching building and student apartment can be employed to install solar photovoltaic panels, obtaining additional energy income. Most of university buildings roofs, designed simply, with 5-6 floors, can be utilized to closely install the solar photovoltaic power generation modules, thus reducing the adverse effects of wind and shelter. Moreover, the centralized layout of roof photovoltaic power generation system can form the scale effect, resulting in reducing the unit cost, having immense economic benefits. Photovoltaic power generation in colleges and universities can not only meet the autonomous energy demand of campus, but also transfer the surplus power to the distribution network for other loading during the winter and summer vacation. Because 1 m² of solar photovoltaic panels can generate 0.8 Kwh of electricity per day, 20,000 m² of solar photovoltaic panels installed on 198,000 m² building of Chang'an campus can generate 16,000 Kwh of electricity per day.

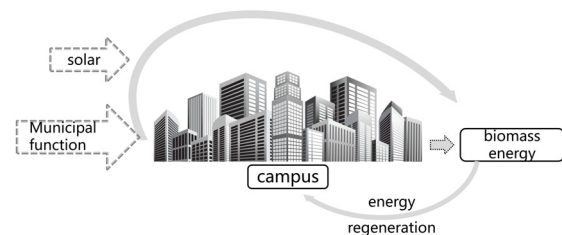


Fig. 7. Campus energy cycle



Fig. 8. Campus dormitory building



Fig. 9. Campus dormitory building

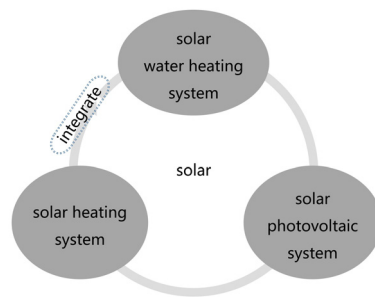


Fig.10.Schematic diagram of solar energy utilization system in campus

Heat:Central heating can effectively improve the living environment in winter,however college campuses are generally warmed by burning coal,mainly ascribed to the practical factors such as remote location,scattered layout and far away from the urban heating pipe network, which consumes a large amount of coal every year, and causes the serious environment pollution.As a new choice of decentralized heating,the integrated carbon crystal heating from solar photovoltaic panel feature merits of energy saving,high efficiency,clear, environmental protection and comfort. By calculation, 1 m² of solar photovoltaic can provide sufficient electricity for the heating demand of 3-4 m².204,000m² of dormitory in Chang'an campus need the installation of around 60,000 m² solar photovoltaic panels to make sure the demand of winter interior heating. During the off-heating period, the generated solar photovoltaic power can also be provided to the national grid for the additional income.

Cooking: Natural gas are widely used in the regular cooking currently. To reduce the input of natural gas and save energy, biogas transportation pipelines can be installed,and biogas can be obtained from the fermentation of kitchen waste and fecal in the campus. According to the daily consumption of 0.4 m³ methane per capita^[6], 2.57 million m³ of methane will be annually consumed on Chang'an campus by the total of 23,000 teachers and students during 280d of school time. However,2.35 million m³ of biogas from the fermentation of kitchen waste, plus 0.22 million m³ of biogas from the fermentation of feces,can basically achieve gas balance.

5 Conclusion

Based on the above analysis, the integrated ecological circulating model of organic waste biogas fermentation, rainwater collection and constructed wetland sewage treatment, photovoltaic solar power generation, carbon crystal heating infrastructure, can effectively promote the circulating metabolism of material and energy on campus, thus reducing the input of material and energy, lowering down the waste output and alleviating the environmental pressure. Meanwhile, these infrastructures possess virtues of simple operation, mature technology, easy replication, slight impact on the existing building. Besides, the artificial wetlands can efficiently beautify the environment, the integration of photovoltaic solar

power generation and carbon crystal heating infrastructure can greatly improve the indoor living environment in winter.

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