

Exploration of green campus construction path based on carbon footprint

-- Taking Sichuan Vocational College of Chemical Industry as an example

Ailin Zhang, Shishi Li

Economic Management Department, Sichuan Vocational College of Chemical Industry, Sichuan Province, China

Abstract: Carbon neutrality action is a consensus strategy for the global response to climate change. Colleges and universities are an important part of cities, and it is of great significance to society to take the lead in achieving carbon neutrality. From the perspective of life cycle, considering the direct carbon emissions within the university system boundary, as well as the indirect emissions generated by purchased electricity, commuter transportation, key supporting materials and major wastes in the upstream and downstream respectively, this paper draws the carbon footprint list of Sichuan Vocational College of Chemical Industry and establishes an indicator evaluation system. The results show that the total carbon footprint of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year are 6082.43 t CO_{2e}, of which 40% of the carbon emissions generated by purchased electricity are the main source of carbon emissions.

Keywords: Carbon footprint; Green Campus; Accounting index evaluation system.

1. Introduction

The carbon neutral strategy is an important driver to achieve social and ecological transformation. Colleges and universities are the main participants in achieving energy conservation and carbon reduction, and they take the lead in achieving carbon neutrality on campus, which has a strong demonstration role for the whole society. Colleges and universities have the characteristics of large number of people, large scale, high energy consumption, high carbon emission units. In recent years, colleges and universities have explored the carbon footprint in a certain depth and breadth, and many colleges and universities have preliminarily obtained the composition of the campus carbon footprint. M.-X. Liang [1] drew on the research of urban carbon sequestration, took Beijing Normal University as an example, and established a “campus carbon cycle model” by using the carbon footprint method, estimated that the carbon sequestration gap of the university in 2007 was 3676 t, and put forward suggestions on ecological landscape planning to improve the carbon sink capacity of campus green space. T. Zhang [2] calculated the CO₂ emissions of different functional areas of Three Gorges University in 2009 using the carbon footprint method, and made suggestions from four perspectives. Due to the disunity of accounting methods, it is difficult to compare and analyze the data among colleges and universities. Although some suggestions have been put forward, they lack a clear purpose. Based on the qualitative research and quantitative accounting analysis of the carbon footprint of Sichuan Vocational College of Chemical Industry, this paper establishes a quantitative indicator system, uses the carbon footprint indicator system to guide the campus energy conservation and carbon reduction, explores the path of green campus construction in colleges and universities, and puts forward corresponding strategies.

2. Data and research methods

2.1. Research object

Sichuan Vocational College of Chemical Industry is a chemical vocational college in southwest China. It is known as the “Huangpu Military Academy of Western Chemical Vocational Education” and the “cradle of highly skilled chemical talents in China”. The school is located in the core area of Craftsman City in western China, with a superior geographical location. The colleges cover an area of 60 hm², with more than 12000 students and 784 faculty. Colleges and universities are significantly different from other administrative systems. When drawing the carbon footprint list of colleges and universities, this paper considers the characteristics of college teaching. Only by accounting in academic years rather than natural years can we better reflect the characteristics of college carbon emissions in the teaching cycle, so as to determine the emission reduction potential and the path of green campus construction.

2.2. Research boundary

Carbon footprint represents the “carbon consumption” of a person or a group [3], focusing on the amount of CO₂, CH₄ and other greenhouse gases emitted by people during various social activities, usually expressed in terms of mass or area [4]. The university carbon footprint refers to the sum of direct carbon emissions from energy and non-energy activities carried out within the university geographical boundary and indirect carbon emissions occurring outside the university boundary in order to maintain its own development and good operation. As shown in Figure 1. In this study, carbon emissions include CO₂, CH₄, N₂O, CF₄ and other fluorine-containing gases, which are represented by CO_{2e}.

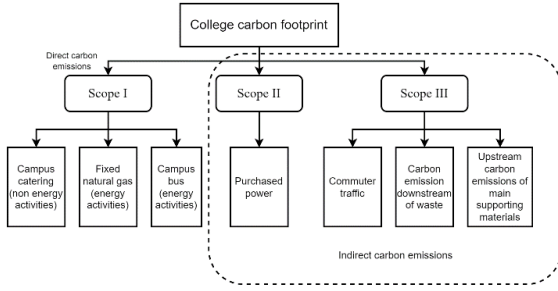


Figure 1. College carbon footprint

2.3. Calculation method

At present, the carbon emission accounting methods for Scope I and Scope II have been relatively unified, mainly in the form of “multiplying activity level data and emission factors”. In the accounting process, the P-LCA method is mainly used to account for the direct carbon emissions in Scope I, the indirect carbon emissions caused by the purchased power in Scope II, and the indirect carbon emissions generated by the downstream treatment of commuting traffic and waste in Scope III. The indirect carbon emissions of Scope II are calculated by multiplying the purchased electricity of colleges and universities by the local grid emission factors. For the carbon emissions of commuting traffic in Scope III, refer to the research of J.-Y. Lin, et al. [5] and adopt the vehicle mileage (VMT) method. For VMTs arriving at universities from other regions of the city and VMTs arriving at other regions of the city from universities, the principle of taking half of each is adopted. Commuter traffic only involves road transportation, so only the carbon emissions generated by fuel consumption originating from universities are calculated. The calculation formula is as follows:

$$D = H \times g = H \times (VMT_2/VMT_0) \quad (1)$$

D refers to the carbon emissions of commuting transportation in colleges and universities; H represents the total carbon emissions of such commuting transportation; g is the responsibility coefficient of colleges and universities in the carbon emission of this commuting mode, and its value is equal to the ratio of college VTM2 to total VTM0; VTM0 represents the driving mileage of vehicles from other regions of the city to universities, and VTM2 represents the driving mileage of vehicles from universities to other regions of the city. Due to the limitation of data availability, if VTM0=VTM2, the g value is taken as 0.5.

For the carbon emission accounting of downstream waste, the main considerations are campus domestic waste, kitchen waste and experimental waste. The disposal gap of different wastes in colleges and universities is mainly obtained through the investigation of different waste disposal gaps in the city. The carbon emission factors of different types of wastes are from the Carbontop carbon emission factor database. The calculation formula is as follows:

$$m_i = n_i \times y_i \times k_i \quad (2)$$

m_i is the carbon emission during downstream treatment of type i waste; n_i is the total amount of the waste generated; y_i is the disposal gap of such wastes; k_i is the carbon emission coefficient of such wastes; i Corresponding to different types of waste, including campus domestic waste, kitchen waste and experimental waste.

The main supporting materials needed to maintain the university’s functionality are usually supplied by the outside world. The carbon emissions indirectly generated in the

upstream production, processing, transportation and other processes are accounted for using the EIO-LCA method [6]. The food, energy and water needed by colleges and universities are purchased from outside. EIO-LCA method can be used to calculate and analyze the implied carbon emissions of the upstream industrial chain of the main materials in Scope III. The calculation formula of EIO-LCA method is shown in (3) – (5).

The basic input-output model is as follows:

$$x_i = (I - A)^{-1}y_i \quad (3)$$

The column vector x is the total amount of various elements that generate carbon footprints; I is the identity matrix; A is the direct consumption coefficient matrix (A obtained from China’s overall data accounting is used to replace A of colleges and universities in this paper); Column vector y is the final element vector; $(I-A)^{-1}$ is Leontief inverse matrix; i is the corresponding production department of the studied material.

The carbon emissions of each department in the production chain are calculated as follows:

$$b_i = R x_i \quad (4)$$

b_i is the amount of CO₂e emitted in production to meet the final demand y_i ; R is a determined row vector, and its element corresponds to the CO₂e amount directly emitted by the unit monetary output of each department. The element value is obtained from Formula (5):

$$R_i = c_i/x_i \quad (5)$$

R_i is the direct emission coefficient of sector i , and c_i is the direct carbon emission of the sector; x_i is the total output of the sector.

2.4. Data sources

The data required for this paper are mainly obtained from the statistical data of the Logistics Department and the Security Department of Sichuan Vocational College of Chemical Industry, the official website statistical yearbook, references, databases, and campus research, as follows:

For scope I, this paper mainly refers to the Data Set of China’s Urban Carbon Dioxide Emissions (2020), the statistical data of the energy consumption of school vehicles of the Logistics Department, and the statistical yearbook data on the official website for accounting. For scope II, mainly refer to the outsourcing power data of the Logistics Department, Sichuan Statistical Yearbook 2021 and China Statistical Yearbook 2021, and multiply the outsourcing power by the regional grid emission factor of the university. For Scope III, the commuting data comes from the statistics of self-use vehicles of the staff of the Security Office and customized bus operation data. The data of key substances and wastes are from the statistics of the Logistics Department, the Carbontop carbon emission factor database and field research.

3. Carbon footprint accounting

3.1. Overall analysis of carbon footprint

Table 1 and Figure 2 show the carbon footprint results of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year and the carbon emission structure of each scope. The total carbon footprint of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year are 6082.43 t CO₂e, and the carbon emissions and proportions of each scope are:

For scope I, the direct carbon emissions caused by energy activities and non energy activities consumed by college staff and students are 1411.89 t CO₂e, accounting for 23% of the total carbon footprint.

For scope II, the indirect carbon emissions caused by the consumption of purchased electricity by universities are 2408.13 t CO₂e, accounting for 40% of the total carbon footprint.

For Scope III, scope III emissions from universities are 2262.41 t CO₂e, which is 37% of the total carbon footprint.

Table 1. The carbon footprint results of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year

Carbon emission scope	classification	Classified carbon emissions/t	Total/t
scope I	Transportation on campus	30.04	1411.89
	Fixed source natural gas	751.08	
	Campus catering(non energy activities)	630.77	
scope II	Purchased electricity	2408.13	2408.13
Scope III	Key supporting materials	1485.63	2262.41
	Commuter traffic	181.32	
	Campus waste	595.46	

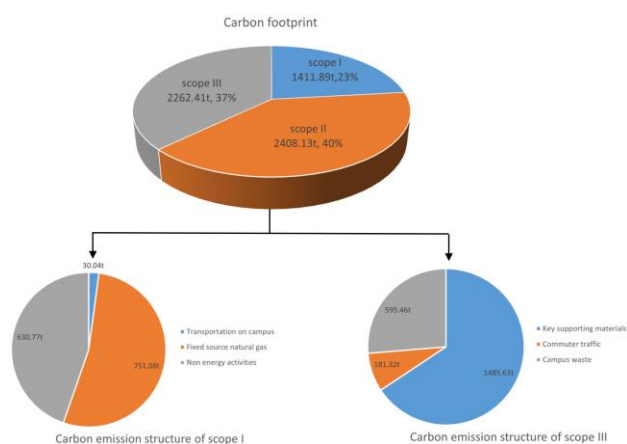


Figure 2. The carbon footprint structure of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year

3.2. Direct carbon emissions (Scope I)

The direct carbon emissions (scope I) of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year are 1411.89 t CO₂e. At present, the on-campus buses have achieved carbon reduction through electrification and new energy vehicles. The direct carbon emission from the oil used for sanitation vehicles are 30.04 t CO₂e. The direct carbon emission from fixed source natural gas are 751.08 t CO₂e. Referring to the research of Wang Qiang et al. [7], it is calculated that the direct carbon emissions caused by non-energy activities on campus are 630.77 t CO₂e.

3.3. Indirect carbon emissions (Scope II and III)

The indirect carbon emissions (Scope II and III) of Sichuan Vocational College of Chemical Industry in the second semester of the 2021-2022 academic year are 4670.54 t CO₂e,

accounting for 77% of the total carbon footprint of the university. According to Sichuan Statistical Yearbook 2021, the loss of power transmission and distribution is 7.37%. According to China Statistical Yearbook 2021, the grid emission factor is 5.810 t CO₂e/10000 kw·h. Through accounting, the indirect carbon emissions caused by purchased electricity (scope II) are 2408.13 t CO₂e, accounting for 52% of the indirect carbon emissions of universities. The indirect carbon emissions caused by Scope III are 2262.41 t CO₂e, accounting for 48% of the indirect carbon emissions of universities. In the indirect carbon emission structure caused by Scope III, the carbon emissions implied by the upstream supply chain of key supporting materials, the indirect carbon emissions caused by commuting, and the carbon emissions implied by the downstream disposal of waste account for 66%, 8%, and 26% of the carbon emissions of Scope III, respectively.

According to the statistics of self-driving commuter traffic of faculty and staff of the Security Department and the operation data of customized bus routes of universities, it is calculated that the indirect carbon emissions generated by commuter traffic in the second semester of the 2021-2022 academic year of Sichuan Vocational College of Chemical Industry are 181.32 t CO₂e. The indirect carbon emissions from self-driving commuter traffic are 130.51 t CO₂e, the indirect carbon emissions from fixed bus commuting are 50.81 t CO₂e.

For the food, energy and water purchased by Sichuan Vocational College of Chemical Industry, which are key substances to maintain the university's functionality, the total implied carbon emissions of the upstream supply chain are 1485.63 t CO₂e, accounting for 24% of the university's carbon footprint. Among them, the implicit carbon emissions of the upstream supply chain of food, energy and water accounted for 22%, 59% and 19% of the implicit carbon emissions of the main materials in turn (as shown in Figure 3).

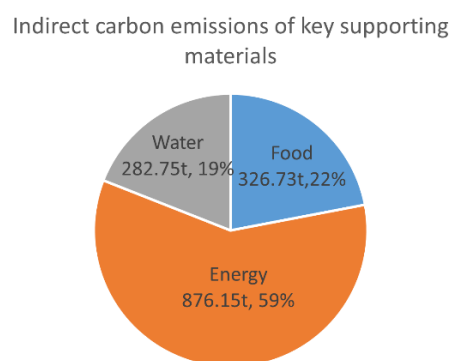


Figure 3. Indirect carbon emissions of key supporting materials

The waste of Sichuan Vocational College of Chemical Industry mainly includes domestic waste, kitchen waste and experimental waste. The carbon emission factors of various wastes are obtained from the Carbontop carbon emission factor database. After accounting, the total implicit carbon emissions of downstream treatment of waste are 595.46 t CO₂e, including 413.91 t CO₂e of domestic waste, 171.34 t CO₂e of kitchen waste, and 10.21 t CO₂e of experimental waste, which respectively account for 69%, 29%, and 2% of the implicit carbon emissions of downstream treatment of waste, as shown in Figure 4.

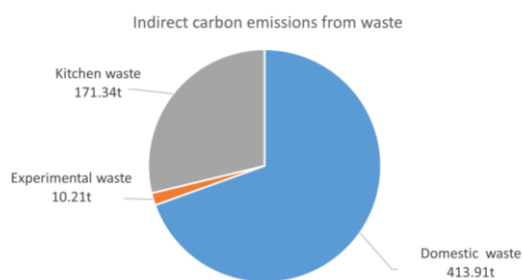


Figure 4. Indirect carbon emissions from waste

4. Carbon footprint accounting index evaluation system

According to the carbon footprint accounting, the carbon footprint of the three scope is summarized, and the carbon footprint list of the second semester of the 2021-2022 academic year of Sichuan Vocational College of Chemical Industry is drawn, as shown in Table 1. In combination with the carbon footprint indicator system of colleges and universities[8], the carbon footprint accounting indicator evaluation system of Sichuan Vocational College of Chemical Industry is established, as shown in Table 2.

Table 2. Carbon footprint accounting index evaluation system

Categories	Index
scale indicator	Transportation on campus\ Fixed source natural gas\ Cumpus catering\ Purchased electricity\ Key supporting materials\ Commuter traffic\ Campus waste
structure indicator	non energy activities\ energy activities
intensity indicator	Carbon emissions per capita

According to the indicator dimension, it is set into three categories: scale indicator, structure indicator and intensity indicator. Scale indicators mainly describe the distribution of the carbon footprint of the entire campus, including absolute quantitative indicators and relative quantitative indicators. The structure index mainly describes the carbon footprint structure caused by the energy structure. The intensity indicator is used to describe the impact depth of carbon footprint from an economic perspective.

According to the evaluation system of carbon footprint accounting indicators, colleges and universities collect daily data corresponding to corresponding indicators to form a carbon emission inventory that can be monitored, reported and verified. The carbon footprint accounting indicator evaluation system can clearly show the current situation of carbon emissions in colleges and universities, determine the potential and path of emission reduction, so as to reduce carbon in corresponding indicator projects and achieve the goal of carbon neutrality.

5. Exploration on the path of green campus construction

From the perspective of life cycle, considering the direct carbon emissions within the university system boundary, as well as the indirect emissions generated by purchased electricity, commuter transportation, key supporting materials and major wastes in the upstream and downstream respectively, this paper draws the carbon footprint list of

Sichuan Vocational College of Chemical Industry and establishes an indicator evaluation system. According to the carbon footprint list, this paper proposes a targeted strategy for green campus construction. The specific strategy recommendations are as follows:

1) Establish a carbon footprint platform that can be monitored, reported and verified. Monitoring, reporting and verification are the basic requirements for tackling climate change. To achieve the goal of carbon neutrality, colleges and universities must clearly understand their daily carbon emissions, predict their carbon emissions in each academic year through daily data monitoring and analysis, and save energy and reduce carbon. Therefore, an open carbon footprint system platform that can be monitored, reported and verified should be established on the basis of the carbon footprint list of colleges and universities to effectively supervise the performance of environmental responsibilities by organizations.

2) Develop a carbon neutral schedule with scientific basis, including step-by-step goals and their realization time. Based on the actual carbon emission and financial situation of the University, the scientific emission reduction target can be formulated. According to the principle of classification and time sharing, the carbon neutralization schedule and implementation strategy of Scope I, Scope II and Scope III can be formulated respectively, so as to achieve the carbon neutralization of Scope I and Scope II as soon as possible, and achieve the carbon neutralization of Scope III in an orderly manner.

3) Develop an orderly campus carbon emission reduction project. On the basis of the carbon neutrality timetable and the achievement of the goal, according to the total carbon emission and structure of the campus, reasonable and effective emission reduction projects are adopted to reduce the carbon emissions of buildings and transportation during the operation of the campus. The arrangement of emission reduction projects should be orderly, not only to achieve emission reduction targets, but also to consider the financial pressure of universities, and other institutions can jointly promote emission reduction projects to alleviate the financial pressure of universities.

4) Diversified campus carbon neutral education. Colleges and universities should actively implement the action of carbon neutral talent training and quality improvement, and guide carbon neutral education to be integrated into the curriculum system of various disciplines. Promote the classification and recycling of campus garbage, encourage teachers and students to save energy and reduce carbon, and encourage the formation of a carbon neutral culture on campus through incentive mechanisms such as carbon credits and carbon inclusion. Guide teachers and students not only to save energy and reduce carbon emissions on campus, but also encourage teachers and students to go out of campus, into the community and society, and carry out carbon neutrality public welfare publicity activities.

References

- [1] M.-X. Liang, "Preliminary Study on Green Space Carbon Sink of Capital Normal University." *Journal of Mianyang Normal University* 29(2010):109-114.
- [2] T. Zhang, X. Zhang, et al. "Calculation of campus carbon footprint -- taking Three Gorges University as an example." *Popular Science and Technology* 14(2012): 102-104+79.

- [3] R. Guo, Y.-H. Tian, "Low carbon oriented campus energy carbon accounting method and its application." *Journal of Tongji University:Natural Science Edition* 43(2015): 1361-1366.
- [4] S.-P. Geng, " A preliminary study on the planning of low carbon campus: a case study of Shenyang architectural university." *Environmental Protection and Circular Economy* 35(2015):43-47.
- [5] J.-Y. Lin, F.-X. Meng, et al. "Carbon footprint analysis of urban energy use -- taking Xiamen as an example." *Journal of Ecology* 32(2012):3782-3794.
- [6] MARCOTULLIO P J, SARZYNSKI A, ALBRECHT J, et al. "The geography of global urban greenhouse gas emissions: an exploratory analysis." *Climatic Change* 121(2013):621-634.
- [7] D. Wang, X.-W. Xu, et al. "Research on Low Carbon Campus Based on the Carbon Footprint Theory -- Taking Chizhou Vocational and Technical College as an Example." *Green Science and Technology* 06(2017):61-62.
- [8] X. Wu, Y.-N. Liu, et al. "Research on College Carbon Footprint Index System Accounting and Emission Reduction Strategy: Taking Northwest University as an Example." *Environmental Science and Technology* 42(2019):187-193.