

Investigation on the Application of Green Energy Resource and Energy Saving and Emission Reduction Technology in Beijing Colleges and Universities and Its Countermeasures and Suggestions

Taking North China Electric Power University as an Example

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Abstract—Based on literature, questionnaires and interviews, this survey analyzes the awareness of green energy, energy saving and emission reduction and its application status and problems in North China Electric Power University, and compares them with other universities in the region. Based on the advanced experience both domestically and internationally, from the management, technology, culture and talent level, this paper aims to propose countermeasures and suggestions for the green energy-saving development of this university, construct strategic organization management system and incentive mechanism, enhance the awareness of green energy conservation and campus culture, promote the introduction of advanced green energy-saving technologies and talents, and enhance the spillover effect of green technology on society and the role of radiation to create a model green energy-saving college brand.

Keywords—universities; green energy; energy saving and emission reduction technology; brand

I. INTRODUCTION

A. Research Background and Significance

As an intelligent knowledge carrier, colleges and universities play an important role in China's strategic emerging industries and green development of energy saving and emission reduction. North China Electric Power University, as a double first-class university with green energy resource research expertise, concentrates a large number of outstanding human talent resources and has the potential of green product innovation. As a result, it should play the leading role in the construction of conservation-oriented green campus.

As a major energy consumer, colleges and universities have great potential in green construction. As a result, they should walk on the forefront of development and become experimental places and demonstration bases for sustainable development. This work has an important demonstration effect and practical significance in promoting the green development of North China Electric Power University and playing the radiation driving role to the surrounding areas.

B. Research Objects and Methods

1) *Documentary method*: Through reading a large number of documents, the author learns from the application situation of green energy resource and energy-saving technology in colleges and universities at home and abroad, understands the relevant theoretical knowledge and green campus evaluation criterion to provide research thoughts and reference models for carrying out research.

2) *Questionnaire method*: The team members distribute survey questionnaires to four universities including North China Electric Power University, Tsinghua University, Beijing University of Technology and Capital University of Economics and Business. Among them, 115 copies are distributed to North China Electric Power University and 85 copies are distributed to the other three universities. The team members carry out analysis on the reliability and correlation of the survey questionnaires by adopting SPSS software.

3) *Interview method*: The team members conduct structured interviews with the administrative staff of the infrastructure construction department, the teachers of the school of economics and management and the students of renewable school of North China Electric Power University.

The interview details mainly cover the application situation of school latest energy-saving technology and the energy-saving consciousness of the teaching and administrative staff; and conduct non-structured interviews with the residents of surrounding communities to acquire more comprehensive information.

4) *Observational method*: The team members carry out observation and investigation on the application of energy-saving technology in North China Electric Power University, comprehensively record all energy-saving facilities and buildings, and observe the use condition of energy-saving equipment by teaching and administrative staff and students.

II. THEORETICAL BASIS AND LITERATURE REVIEW

A. Theoretical Basis

1) *Theory of public goods*: In 1954, Samuelson defined public goods as: public goods refer to such a product, and everyone's consumption of this product does not reduce the consumption of this product by any other person. Public goods or labour services have three characteristics: indivisibility of utility, non-competitiveness of consumption and non-exclusiveness of benefits. Because of the phenomenon of "market failure", it is difficult for market mechanism to achieve "Pareto Optimality" in terms of public goods. If provided by the market, there will inevitably be "free riders" that will lead to "public tragedy", and it is difficult to maximize the public interests of all members of society.

2) *Incentive theory*: Incentive theory refers to the theory of researching how to arouse people's enthusiasm. It believes that work efficiency and labor efficiency are directly related to workers' working attitude that depends on the satisfaction degree of needs and incentives. For example, Maslow, an American psychologist, divides human various needs into five levels: physiological needs, safety needs, social needs, respect needs and self-fulfillment needs. He believes that people pursue satisfaction according to the level of needs. Therefore, managers can play an incentive function by setting up goals according to needs.

B. Literature Review

1) *Domestic status quo*: In recent years, some domestic colleges and universities in China have applied energy saving and emission reduction technology to campus facilities, and achieved good results. For example, South China University of Technology has actively carried out the research on the centralized supervision system of energy saving for urban air-conditioning, and developed a series of achievements, such as the integrated optimization management and control system of central air-conditioning energy saving, and the refrigerating capacity management and control system of the secondary refrigerating capacity station for regional centralized cooling. The supervisory platform of Tongji University implant the authoritative building simulation software developed by the United States

Department of Energy to forecast the trend of energy consumption and evaluate the effect of energy-saving countermeasures. Through the construction of conservation-oriented campus, Zhejiang University has formed a four-in-one campus energy-saving management system that is characterized by energy consumption monitoring, energy consumption statistics, energy audit and energy efficiency publicity of campus architectures. Tianjin University has made the energy-saving work of campus architectures more scientific, orderly and efficient by means of carrying out on-the-spot investigation on and energy consumption statistics of campus architectures, energy audit of campus and architectures, implementation of energy consumption monitoring platform and construction of energy-saving operation management system. (Liu Meng [2], 2007)

2) *Foreign status quo*: Compared with domestic colleges and universities, foreign colleges and universities have a long history when it comes to the application of energy-saving technology in campus. The United States and Canada are the earliest countries to carry out the green university program. In 1994, George Washington University in United States started on the pioneer project of green university that focused on turning it into the first green university in the United States and beyond. Cornell University adopts lake water for cooling in order to reduce cooling energy consumption in summer. (Liu Meng [2], 2007) In some economically underdeveloped areas, the application of energy saving and emission reduction technology in campus has also gained great attention. Univ Budi Luhur University in Indonesia reduces energy demand by effectively utilizing electricity, such as the method of turning off the lights in rooms when not in use. (Riyanto [3], 2018) In the field of energy-saving technology research, Hasapis [4] (2017) introduces the major procedures to achieve energy independence in the design of large-scale photovoltaic power generation devices in colleges and universities. By taking the campus of Technical University of Crete as an example, the feasibility research of photovoltaic power generation is carried out while analyzing the energy consumption data of buildings on campus, so as to reveal its potential contribution and applicability.

Generally speaking, the implementation of energy-saving technology in China's colleges and universities benefits by the late-mover advantage, advanced technology and comprehensive coverage. The national finance has vigorously supported the construction of conservation-based campus of colleges and universities. So far, about 1 billion yuan has been subsidized to seven batches of 227 colleges and universities to carry out the "demonstrative project for the construction of conservation-based campus energy-saving supervision system". A series of technical guides, statistics, auditing, notice-filing and evaluation method for the construction and management of energy-saving supervision system for campus buildings have been completed, which has played an excellent demonstration role (Zhang Jun et al. [1], 2018). However, some colleges and

universities in China have not established a systematic system of publicity, education, management and energy auditing due to the restrictions of technological merit and economic conditions or the backwardness of consciousness.

III. SURVEY ANALYSIS

A. Investigation and Survey Process

1) *Observation and investigation:* The team members carry out observation and investigation in North China Electric Power University to investigate the fundamental state of the campus and the current situation of energy-saving development.

a) *Summary of the fundamental state of campus:* Located in the vicinity of Huilongguan community, North China Electric Power University consists of one main building, five teaching buildings, library, three canteens, bathrooms and other buildings, except for the land for science and technology parks to be developed, with a total campus area of 1600 mu. The planning and development mode is "one core and two axes" to form the north-south axis and the east-west axis with the library as the core of the whole campus.

b) *Current situation of campus energy saving:* Team members count energy-saving buildings and facilities in North China Electric Power University, and understand the application of energy-saving technology. Results are shown in "Table I".

TABLE I. INTRODUCTION OF ENERGY-SAVING TECHNOLOGY OR FACILITY

Energy-saving Technology or Facilities	Application Location	Specific Introduction
Solar power bathroom	Public bathroom	It can accumulate more solar heat on a smaller heat collection area with the feature of easy to operate and fully automatic control
Energy-saving street lamp; indoor LED lamp	Road and indoor	LED lamp and energy-saving street lamp represented by new light source meet the relevant standards of road lighting through light distribution design, and make high use of light efficiency with high reflectivity reflector.
Roof photovoltaic power generation	Teaching building roof	The teaching building roof uses the photovoltaic effect of semiconductor interface to directly convert light energy into electricity, thus forming photovoltaic power generation device.
Solar power environmental protection waste bin	Both sides of the road	It simultaneously has the functions of charging and garbage sorting to facilitate students' life.
New energy vehicle charging pile	On Campus	Installed in each teaching building, it can charge various types of electric vehicles according to different voltage levels.

Energy-saving Technology or Facilities	Application Location	Specific Introduction
Intelligent lighting system	Classroom	The system can output an optimum lighting power to the lamp, which can make the light ray emitted by lighting much softer, distribute the lighting more evenly, and save electric energy by a large margin. In addition, it will prolong the lamp life and reduce maintenance costs.

Generally speaking, the campus area of North China Electric Power University is gradually extending, so the buildings are dense. However, school still mainly adopts traditional energy-saving methods such as solar power bathroom and roof photovoltaic power generation. With the promotion of technology and policy support, intelligent lighting control system and new energy vehicle charging piles are becoming more and more popular.

2) *Questionnaire survey:* The team members design the survey questionnaires according to the thinking and questions produced in the course of observation and investigation, and carry out the questionnaire survey among 200 students of North China Electric Power University, Tsinghua University, Beijing University of Technology and Capital University of Economics and Business. The purpose is to understand the students' understanding and application of energy-saving facilities on campus and the intensity of their energy-saving consciousness, and carry out feedback on their awareness of energy-saving behavior and the construction and publicity of energy-saving design of school.

a) *Sample survey of North China Electric Power University:* First of all, the students of North China Electric Power University are selected as samples to carry out the investigation and research, and the credibility and correlation of the questionnaire are analyzed by adopting SPSS software.

- Understanding and utilization of energy-saving facilities

Students learn more information about energy-saving facilities, but the channels are single. They mainly learn information about energy-saving facilities through direct observation, and the way of official account push and official website news propaganda are general. The utilization rate of students' energy-saving facilities is low.

- Survey of energy-saving behavior awareness

Student's awareness intensity of energy-saving behavior is researched from the starting point of students' setting of air-conditioning temperature in dormitory in summer. In terms of students' self-cognition of energy-saving consciousness, some students hold that they possess a strong awareness of energy-saving, but they still need to step forward.

Pearson correlation coefficient is adopted to describe the correlativity between the attention of green energy policy and application of energy-saving technology and the cognition of energy-saving awareness, and the strong and weak circumstances of coefficient is defined. The correlation coefficient value is 0.273, and shows a significant level of 0.01, which indicates that there is a significant positive correlation between them.

- Expectations for the development of energy-saving technology on campus in the future

Students suggest improving the technology of solar power hot water, garbage classification management, air conditioning energy-saving and other aspects.

b) Sample comparison research of universities in Beijing: In view of the basic orientation of our university, this paper selects three universities in Beijing and compares North China Electric Power University with them.

- Understanding of energy-saving facilities

Students at large learn information about energy-saving facilities on campus through direct observation. Other channels, such as official account push, teacher explanation in the class and official website news, are much less. Students generally have a slightly monotonous understanding channel, so school should strengthen the propaganda degree.

- Survey of energy-saving behavior awareness

By contrast, energy-saving behavior is more common in the other three universities. A large proportion of students never pack their meals in plastic lunch boxes to return to their dormitories and use disposable chopsticks provided by the dining hall. However, it is a very extremely common problem for students in colleges and universities to charge their electronic equipment in their dormitories when they go out.

c) Analysis of results

- In terms of students' understanding and utilization of energy-saving facilities on campus, students know more about energy-saving facilities, but the channels are single, and most energy-saving facilities are less used. School should open up and innovate publicity channels, strengthen publicity effect and improve the utilization rate of energy-saving facilities;
- In the aspect of investigation of energy-saving behavior awareness, students have an ordinary awareness of energy-saving and emission reduction. As for the much lower attention paid to relevant policies and technologies and the lack of execution, it is necessary to fundamentally raise awareness, so as to make the energy-saving behavior transition from the learning stage to the subconscious stage.
- In the process of comparison with other colleges and universities, it is found that the application of green energy and energy saving and emission reduction technology in other colleges and universities is

generally similar, except for the economical demonstrative colleges and universities, and the leading role of our university with energy superiority has not been fully reflected.

3) *Special interview:* On the basis of questionnaire survey, the research group carries out special interviews with administrative staff, teachers, students of related majors on campus and community residents off campus to understand the school energy-saving planning and propaganda measures and the radiation driving role to the community.

a) Administrative staff: During the interview with the administrative staff of the infrastructure construction department, the research group learns that the major applied energy-saving facilities on campus are photovoltaic solar power generation technology on the roof of dormitory, automatic lighting system on playground and solar power bathing device. As for energy saving and emission reduction, there is no systematic planning and construction in school.

b) University teachers: During the interview with teachers, the research group learns that most teachers possess a low understanding of energy-saving facilities of school, there are no policies and regulations on energy saving in their departments, and all kinds of expenditures on electricity and water utilization belong to public expenditure, so everyone will not deliberately pay attention to them. Teachers believe that the current problems in the initiate of energy-saving action are largely caused by the publicity of energy-saving behavior, which creates the "hitchhiking" opportunity for most people.

c) Undergraduates majoring in new energy resources: During the interview with the sophomores of renewable energy school, the students say that they mainly learn basic theoretical knowledge and calculation in the class, and usually read news related to new energy application. In the future, the students hope that school will offer relevant courses and apply theory to practice.

d) Community residents: Team members randomly selected three community residents to carry out unstructured interviews in the community around the school by accidental sampling method. As for the impact of North China Electric Power University on energy saving in the community and the application of specific energy-saving technologies in the community, all three of them are barely understand. Residents say they will possess a certain sense of energy saving, but will not buy energy-saving equipment.

e) Analysis of results: The interview results show that the respondents have certain energy-saving potential and awareness, but are short of motivation. Schools should strengthen top-level strategic planning and fully tap the potential of various groups. School is short of strategic planning and propaganda guidance in energy-saving work, is obscure in their strategic positioning. Meanwhile, school lacks the radiation driving role to the surrounding communities.

4) *Comparative analysis of experience of colleges and universities:* In the process of questionnaire survey, the team members find that in the application planning of green energy and energy saving and emission reduction technology, the leading role of Tsinghua University and the dominant position of energy engineering of Beijing University of Technology are in line with the development planning of our university. Therefore, the team members carry out secondary data survey to learn from the experience of planning and construction of energy saving facility of other universities, so as to help our university to carry out the planning and construction of energy saving facility.

a) *Tsinghua University:* In 2009, Tsinghua University was awarded "national advanced unit of energy-saving work in colleges and universities" by the Ministry of Education. Its energy-saving supervision platform gives full play to the discipline advantages of school, employs expert teams to jointly deal with key problems, takes the construction of green universities as the leadership with scientific planning, rational distribution, distribution of the implementation. Meanwhile, it also pays attention to the closed-loop management of energy-saving and consumption reduction, and set an example for the energy-saving management of colleges and universities throughout the country.

b) *Beijing University of Technology:* Beijing University of Technology has incorporated energy saving and emission reduction knowledge into its school education and training system, which is listed as an important content of political and ideological education for college students. It combines the discipline characteristics and professional courses to carry out the education on resource conservation and environmental protection. Meanwhile, it also advocates the building of an energy management system with the guarantee of systematic construction and the backing of technology application to promote the benefits of energy saving by means of technology and education, and forms a campus new energy-saving fashion.

Our school can learn from the energy-saving construction experience of these two schools, give full play to the leading role, and make use of the school's energy advantages to build a green energy-saving leading university in Beijing.

B. Problem Collation

This research group will comb and summarize the problems found in the process of research, which can be divided into three levels:

1) *School:* The image development orientation of the school is obscure. As a university with energy advantage, it has not given full play to the advantages of technology and talent, formed a bright spot of the school, established the brand image of "green energy-saving university", played a leading role in the colleges and universities and radiated it to the whole society.

2) *Administration:* The application of green energy and energy-saving technology in logistics and other departments

is more traditional and less innovative. In the planning and introduction of energy-saving facilities in the future, the strategic direction and implementation schedule need to be clarified. At the same time, the administrative departments are not deeply aware of the importance of propagandizing energy-saving technology, and propaganda work still needs to be strengthened.

3) *Student:* Students possess an ordinary understanding of energy-saving technology, and have a certain awareness of energy-saving but are short of action. Students with relevant majors also are short of the in-depth learning of application practice.

C. Explanation of Reason

According to the analysis, the research team believes that the main reasons for the above-mentioned problems are as follows:

1) *The existence of phenomenon of "hitchhiking":* The positive externality brought by saving public resources can not make individuals get benefits, and the negative externality caused by wasting public resources do not require individuals or school departments to pay the corresponding costs. Therefore, the groups including teaching and administrative staff and students have not incentive to actively save energy and apply energy-saving technology to campus.

2) *Short of implementation of system and responsibility:* The school adopts the way of unified accounting, does not carry out the independent accounting strategy of each department that encourages each department to reduce energy consumption costs by themselves in the way of assuming sole responsibility for their profits and losses, thereby reducing the enthusiasm of energy saving and emission reduction of each department.

3) *Short of effective incentive mechanism:* The construction of energy-saving system needs the joint efforts and cooperation of relevant departments, all departments and teachers and students on campus, but for now, there is short of incentive point in any link.

4) *Short of publicity and guidance:* Neither the school strategic management level nor the grass-roots operation level pay enough attention to energy saving and emission reduction and its technology application, which leads to less channels for students to accept knowledge about energy saving and emission reduction on campus and insufficient publicity and guidance.

IV. COUNTERMEASURES AND SUGGESTIONS

A. Management Level

1) *To establish the overall management department for green energy conservation:* Leading groups for energy saving work should be set up, special management organizations should be established (as shown in "Fig. 1"), and the relevant responsibilities of each post should be defined. Each department and branch should arrange part-

time energy consumption managers to further strengthen energy management.

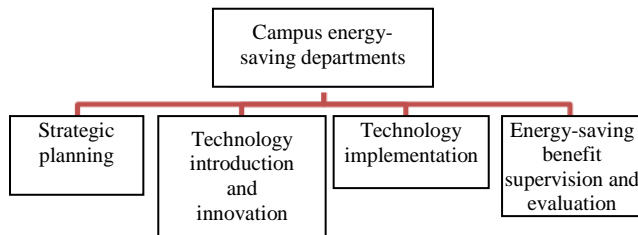


Fig. 1. Functions of campus energy saving department.

As the leader of green energy and energy-saving technology in school, renewable energy school should take the initiative to transform the latest energy-saving technologies into achievements and apply them in school. At the same time, teachers and researchers of renewable energy school can be used as think tanks for strategic planning of campus energy-saving department, and provide professional advice on school energy-saving.

2) *To form a scientific and reasonable incentive mechanism*

a) *To improve energy-saving evaluation system and promulgate corresponding assessment method:* The demands of the personnel participated in the technical implementation process should be satisfied during or after the implementation of the project by means of utilizing the school's own advantages and resources, so as to encourage them to accomplish their tasks better. The energy-saving projects, indicators, scoring principles and policy of reward and punishment should be clearly defined. Considering the demands of teachers and researchers, such as the elevation of competence level and salary level, the school should distribute the benefits or funds saved by introducing new energy-saving technology, incorporate energy-saving achievements into the teacher evaluation system, and reward teaching and administrative staff who participate in the implementation of energy-saving technologies with funds or ratings

b) *Integration of industry-university-research, and cooperation with enterprises to help energy saving and emission reduction in schools:* As the knowledge-intensive organization, colleges and universities have numerous patent projects and cutting-edge scientific research achievements. They can put in place scientific research achievements from papers to real life by means of cooperating with off-campus enterprises. In addition, the campus environment is more stable and safe than that of off-campus. They can be used as pilot projects to test-run cooperative products on campus in the first place and then carry out the promotion. The profits of enterprise should be accordingly allocated to the researchers involved in the project.

c) *To stimulate the subjective initiative and practice of teachers and students of North China Electric Power University:* As for students, relevant energy-saving courses can be offered to improve their knowledge and awareness of energy-saving and cultivate excellent talents in the field of green energy. At the same time, the bottom-up feedback mechanism can be added, such as energy-saving suggestion box, to facilitate teaching and administrative staff and students to timely reflect energy-saving ideas and suggestions to the school leaders, and appropriate incentives should be given in case of the adoption of ideas, such as credits, performance, bonuses, etc.

3) *To create green energy-saving demonstrative pilot area:* As the necessary building in every college and university, the library has the characteristics of dense population and large energy demand. A large number of energy-saving measures can be used by taking library as the pilot project, such as roof solar power generation, energy-saving lighting design, rainwater recycling and so on. Creating an energy-saving library can improve the energy-saving consciousness of teachers and students on campus. After the test the feasibility of technology and economy, and then this project will be promoted to the application of the whole school.

B. Technology Level

North China Electric Power University, as a university with energy advantages, has a strong faculty and facilities and advanced energy technology. Promoting energy saving and emission reduction technology on the campus of North China Electric Power University can get through the double verification of technical feasibility and economic feasibility. On the basis of learning from the construction experience of colleges and universities at home and abroad, and technical proposals suitable for North China Electric Power University are put forward by means of adapting measures to local conditions.

1) *To promote research and development of cutting-edge green energy projects*

a) *Wind-solar complementary street lamp project:* The project has no large amount of electricity expenditure in the later period and is characterized by intelligent control, free of manual operation, simple construction and convenient maintenance, therefore, it can be used roadway lighting on campus.

b) *To develop renewable energy in cooperation with social forces:* Our school can cooperate with State Grid Corporation in technology and with banks in financing to promote green campus construction in virtue of social forces.

2) *To promote demonstrative application of energy-saving technology*

a) *Power-saving technology:* The classroom is uniformly regulated by the central system of intelligent lighting, so as to achieve intelligent "lights go out when people walk out". It is suggested to install in such places as

classroom where the demand for lighting is changing strongly, so as to control energy consumption.

b) Coal-saving technology: Our school can carry out carbon footprint calculation in places where the coal consumption is much larger, hold energy saving and emission reduction weeks, raise teachers and students' awareness of energy saving in the form of competitions, and promote energy saving technology.

c) Water-saving technology: The self-closing faucet is the product that lets the water stop for a certain period of time, and our school applies this technology to promote the management application of water resources. Rainwater collection and treatment system can also be used in our school. Beijing has enjoyed a large amount of precipitation in summer. Meanwhile, rainwater collection and treatment system can utilize and deploy the collected rainwater, such as irrigation and fountains, so as to save water resources.

C. Cultural Level

1) To boost knowledge spillover and radiation effects and improve social benefits: Our school is situated in Huilongguan community where carries a large number of resettlement personnel. As the knowledge-intensive center, it should undertake the social responsibility of promoting energy-saving and emission reduction technology to the surrounding areas. Schools can carry out publicity and education activities in the community, promote the latest energy-saving technology, and assist communities and enterprises to construct a set of energy-saving system, establish an excellent image of green colleges and universities, and form social benefits.

2) To strengthen green energy conservation and cultural propaganda and implement bi-directional driving: The construction of energy conservation and emission reduction is a bi-directional process, which requires not only perfect top-level design, but also inevitably needs the promotion of grass-roots. If the number of grassroots community with excellent energy-saving consciousness grows, it can not only save energy, but also take shape policy force, which will urge the policy-making made by high-level decision-making groups to accommodate the energy use habits of grassroots community and take shape reactive force. The power management department of North China Electric Power University should strengthen the propaganda of school energy-saving achievements, increase relevant professional courses, and give full play to the strength of grass-roots community.

3) To promote talent cultivation and quality construction and play a leading role: North China Electric Power University should establish and improve the mechanism of introducing high-end energy talents and cultivate them. It also should carry out energy-conservation lectures and optional courses in schools, give full play to the discipline advantages of energy universities in order to build the green energy-conservation brand of North China Electric

Power University. North China Electric Power University, as a higher education institution, enjoys strong faculty and facilities and scientific prowess in new energy research. Therefore, it should make full use of its academic advantages to actively promote the research of energy-conservation technology.

V. CONCLUSION

In the future, as for the construction of green energy and energy conservation and emission reduction technology on campus, overall planning should be carried out as a whole, incentive mechanism should be set up to mobilize the enthusiasm of all departments. Meanwhile, the school should learn from advanced technology at home and abroad, and make full use of the advantages of school energy characteristics to play a radiation-driven role in the surrounding areas, so as to achieve green sustainable development.

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