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Analysis of Intelligent Biomass Energy in Energy Monitoring and Consumption Optimization in Physical Education Teaching

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Abstract. Amidst the focus on sustainability and technological advancements, this study explores how intelligent biomass energy can boost physical education efficiency through energy monitoring and consumption optimization. Based on experiments and data analysis, it highlights intelligent biomass energy's potential to provide sustainable support, fulfil teaching needs, improve efficiency, and reduce waste. The paper introduces key concepts of intelligent biomass energy for physical education, offering guidance on its application for energy monitoring and optimization. Analyzing students' physiological data, establishes a scientific teaching foundation, enabling real-time insights and personalized programs tailored to individual differences. The paper also explores the potential application of intelligent biomass energy in physical education, anticipating an increased role with ongoing technological advancements. Offering innovative perspectives for reform and innovation, the study provides valuable insights into the development and implementation of renewable energy technology. The introduction of intelligent biomass energy supports real-time energy consumption monitoring, fostering scientific teaching and optimizing effectiveness. This enhances the scientific and efficient aspects of physical education but also aids students in understanding their physical condition and sports performance, laying a solid foundation for future endeavours.

Key words. Intelligent Biomass Energy, Physical Education, Energy Monitoring, Consumption Optimization.

1. Introduction

Given the escalating global energy crisis and growing environmental concerns, governments and scientific research institutions are directing their focus toward the advancement and utilization of renewable energy [1], [2]. Faced with the problem of environmental and energy shortage, China's traditional Chinese medicine industry needs to adopt advanced drug residue treatment technology to treat a series of traditional Chinese medicine residue, and finally get high temperature crude gas for subsequent production activities, to relieve the pressure of energy shortage and reduce the environmental pollution caused by the utilization of thermal power in the production process. In addition, the application of the gasification recycling process of Chinese medicine residue also solves the problem of discharge and treatment of Chinese residue in Chinese medicine enterprises.

Physical education constitutes a crucial component of school curricula, playing a pivotal role in fostering the holistic development of students, encompassing both their physical and mental well-being. However, the traditional physical education teaching methods often neglect the precise control and management of energy consumption, resulting in uneven teaching effects and unable to meet the diversified needs of modern education [3], [4]. Therefore, the application of intelligent biomass energy in physical education can not only solve the problem of energy waste in traditional teaching but also realize the fine management and personalized teaching of the teaching process through energy monitoring and consumption optimization [5], [6].

After analyzing the current situation of environmental and energy applications in China, combined with the current situation of traditional Chinese medicine residue treatment, this article applies the integrated methods of life cycle assessment and life cycle cost analysis to analyze the comprehensive benefits of biomass energy gasification and recycling systems in terms of environment, economy, and other aspects. The specific content is as follows:

1. Provide a detailed introduction to the methods of life cycle assessment and life cycle cost analysis. Based on this, propose an integrated method for life cycle assessment and life cycle cost analysis, and specifically introduce the integration framework of the integrated method Research methods [7], [8].

2. Deeply understand the process of biomass energy gasification and recycling, and apply the integrated methods of life cycle assessment and life cycle cost analysis to establish a comprehensive evaluation model for the biomass energy gasification and recycling system.

3. Applying a comprehensive evaluation model of biomass energy gasification and recycling system to the traditional Chinese medicine residue treatment system of a pharmaceutical company in Shandong Province, and comparing the traditional Chinese medicine residue gasification and recycling system with the traditional Chinese medicine residue landfill system, the optimal treatment plan for biomass energy based on traditional Chinese medicine residue is identified The research methods applied in this article mainly include literature

research, field research, integrated methods of life cycle assessment and life cycle cost analysis [9], [10]. The specific introduction is as follows:

1. Literature research methods. This article draws on the research achievements of domestic and foreign scholars to understand the current status of biomass energy gasification and the utilization of traditional Chinese medicine residues. It also introduces the integrated methods and their application status of life cycle assessment, life cycle cost analysis, life cycle assessment, and life cycle cost analysis [11], [12]. Therefore, the framework and steps of the integrated methods of life cycle assessment and life cycle cost analysis in this article are proposed.

2. Field research methods. This article conducts on-site research on a pharmaceutical company in Shandong Province to understand a series of process processes for traditional Chinese medicine residue pretreatment, gasification, and gas utilization and collects energy, environmental, and economic-related data for subsequent research.

Integrated method of life cycle assessment and life cycle cost analysis. This article applies this integrated method to comprehensively evaluate the biomass energy gasification and recycling system [13], [14]. Among them, in the life cycle assessment section, the Eco indicator 99 method was applied to calculate the environmental load of the process; In the integration part of the two evaluation methods, to calculate the comprehensive benefits of the system, the Analytic Hierarchy Process (AHP) and the Approximation Ideal Solution Sorting method are applied to rank each system and select the optimal process plan.

2. Application of Intelligent Biomass Energy in Physical Education

Through intelligent biomass energy technology, physical education not only strengthens environmental protection and practical teaching but also deepens students' understanding of sustainability. The key application is to convert waste into clean energy, such as heat and electricity, to power teaching sites and improve energy efficiency. Among them, formula (1) reveals the association between heart rate and energy release.

$$E_{\text{heart}} = \frac{k_{\text{heart}}}{\sqrt{\text{HeartRate}}} \cdot \ln\left(\frac{t^2}{e^{\text{HeartRate}}}\right) \tag{1}$$

Environmental education: Intelligent biomass energy technology can make students understand the utilization of renewable energy and the importance of environmental protection. By imparting students with knowledge regarding the origins, manufacturing procedures, and diverse applications of biomass energy, we can foster a deeper understanding and appreciation of the paramount importance of environmental protection and sustainable development [15], [16].

Practical teaching: In physical education, we can combine intelligent biomass energy technology to carry out some practical teaching activities. For example, students can be organized to collect and treat biomass waste and understand the production process of biomass energy; Or let students know about different types of biomass energy technologies, such as biomass gasification, biomass power generation, etc., and let students practice. The application process of intelligent biomass energy in physical education is shown in Figure 1.

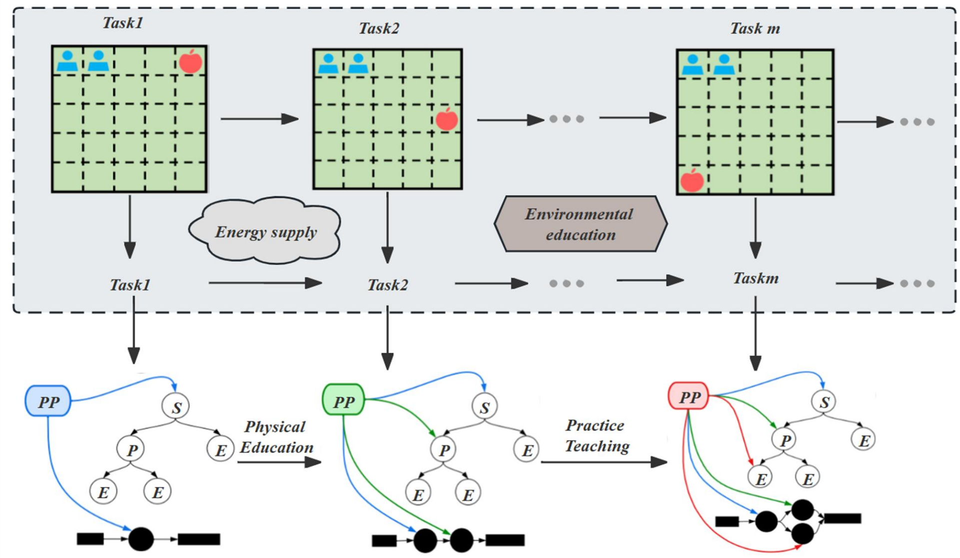

Figure 1. Application Flow Chart of Intelligent Biomass Energy in Physical Education

Noteworthy is the consideration of which biomass energy sources are suitable for student use. Subsequently, this chapter will outline the various types and features of intelligent biomass energy, along with its application forms in the context of physical education.

A. Types and Characteristics of Intelligent Biomass Energy

The types of intelligent biomass energy mainly include biomass solid energy, biomass liquid energy and biomass gas energy [17], [18]. Biomass solid energy mainly includes plant cellulose and hemicellulose such as wood, straw and hemp stalk. Its characteristics include wide sources and easy access; High density, convenient storage and easy transportation; More ash and volatile matter are produced during combustion. Biomass liquid energy mainly includes biodiesel, bioethanol and so on. Its characteristics include that its properties are similar to those of petrochemical oil products, and it can be directly used without modification; However, low energy density and volatility are also problems. Biomass gas energy mainly includes biogas, sawdust gas and so on. Its characteristics include cleanliness and environmental protection, and little environmental impact; However, problems such as low energy density, easy liquefaction and condensation also need to be solved. The use of intelligent biomass energy is shown in Figure 2.

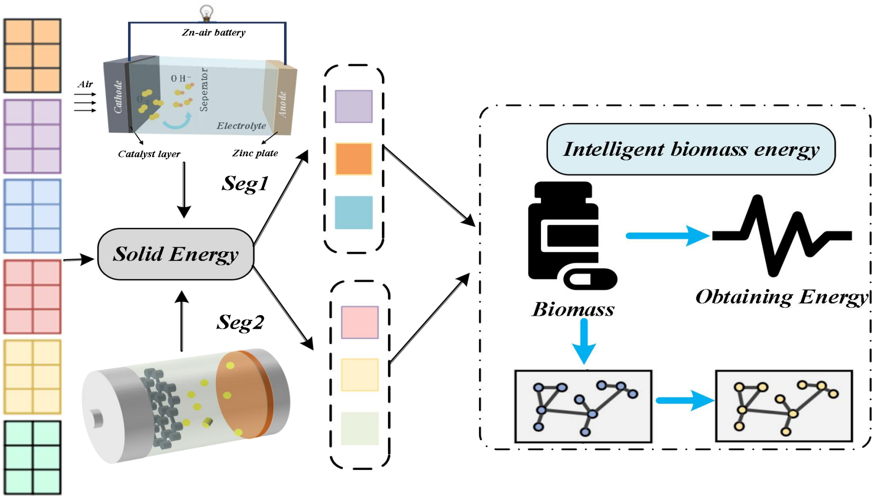

Figure 2. The Application of Intelligent Biomass Energy Sources

In addition, intelligent biomass energy has the characteristics of renewability, environmental protection, diversity and sustainability. Renewability means that the raw materials of biomass energy can be regenerated, such as crops and wastes, will not be exhausted like fossil energy [19], [20]. Environmental protection means that carbon dioxide will not be produced in the combustion process of biomass energy, which has little pollution to the environment. Diversity means that the raw materials of biomass energy can be various plants, wastes, etc., which are rich in sources and diverse in treatment methods.

B. *Application Forms of Intelligent Biomass Energy in Physical Education*

As a renewable and clean energy form, intelligent biomass energy can not only provide continuous energy support for physical education but also optimize the energy consumption in the teaching process. This paper will analyze in detail the application form of intelligent biomass energy in physical education and its role in energy monitoring and consumption optimization [21]. The application forms of intelligent biomass energy in physical education include energy supply, energy monitoring and optimization, and innovative teaching methods and means.

Intelligent biomass energy offers sustainable energy solutions for physical education. Leveraging biomass gasification technology, crop residues and forestry waste are transformed into clean gas, thereby providing heat or electrical energy for indoor gymnasiums and swimming pools. Intelligent biomass energy, a renewable resource, can reduce reliance on traditional energy, lower costs, and reduce pollution. In physical education, it's used for energy monitoring and consumption optimization [22]. Sensors and data systems monitor students' energy consumption during exercise in real time, enabling teachers to optimize methods and intensity based on data analysis. Biomass-powered equipment auto-adjusts parameters for efficient energy use. This technology enables innovative teaching methods, such as VR and intelligent sensors, providing an immersive learning experience [23]. By optimizing energy consumption, teaching methods, and student experience, intelligent biomass energy not only enhances instruction but also fosters environmental awareness and sustainable practices. Looking ahead, as technology advances and policies evolve, it is anticipated that the application of intelligent biomass energy technology in physical education will become more widespread and comprehensive. Simultaneously, as environmental consciousness continues to grow and application costs decrease, it is expected that intelligent biomass energy technology will find even broader applications and further development in the field of physical education.

3. Energy Monitoring and Consumption Optimization Method

A. *Energy Monitoring Methods*

In physical education, the monitoring of students' energy is an important link. By monitoring students' energy consumption, teachers can better understand students' physical fitness, adjust teaching methods and exercise intensity, and optimize teaching effects [24], [25]. The energy detection method for students in physical education class will go through the following steps: equipment selection, equipment wearing, data collection, data processing and analysis, and kinetic energy analysis. In this study, we mainly adopted the intelligent biomass combustion system and the biomass power generation system. The intelligent biomass combustion system reduces the waste of energy by automatically adjusting the combustion efficiency, and the biomass power generation system converts the biomass into electric energy, effectively supplementing the energy demand in physical education. Kinetic energy is the energy related to moving objects, while biomass energy is the energy generated by biochemical processes in organisms. The relationship between kinetic energy and biomass energy is shown in formula (2).

$$E_{\text{kinetic}} = \frac{1}{2} \cdot m \cdot \left(\frac{d}{dt} \left(v^2 \right) \right) \cdot \sin\left(\frac{\pi \cdot t}{T} \right) \tag{2}$$

Biomass energy conversion usually involves biological processes or chemical reactions, which are sensitive to temperature. The influence of temperature change on biomass energy conversion is shown in formula (3).

$$E_{\text{temperature}} = \frac{1}{2} \cdot \left(\frac{dT}{dt} \right)^2 \cdot \cos\left(\frac{\pi \cdot t}{T} \right) \tag{3}$$

Before class, wear the selected equipment on the students. Ensure that the equipment is worn in the correct position and will not affect students' exercise. At the same time, explain the use and wearing precautions of the equipment to students to ensure that students are comfortable and safe during use.

In the process of physical education, the equipment will monitor students' heart rates, exercise intensity and other data in real-time. These data will be transmitted to the data centre or teachers' handheld devices for analysis and evaluation. Ensure the normal operation of equipment, and timely process and analyze data. The relationship between energy loss and motion intensity is usually complex and may be nonlinear. The nonlinear relationship between motion intensity and energy loss is shown in formula (4).

$$E_{intensity} = k_{intensity} \cdot \left(\frac{1}{\sin(Intensity)} + \tan(Intensity) \right) \tag{4}$$

Teachers or data analysts can process and analyze the collected data. By comparing the energy consumption data of different students, teachers can understand students' physical fitness and sports ability [26], [27]. At the same time, teachers can adjust teaching methods and exercise intensity according to the results of data analysis to optimize teaching effect. The efficiency of biomass energy conversion pertains to the effectiveness of transforming chemical energy within organisms into usable energy. This process is affected by many factors, including temperature, metabolic activity, enzyme activity and so on. The time-varying model of biomass energy conversion efficiency is expressed by formula as shown in formula (5).

$$\text{Efficiency}_{\text{bio}} = \frac{\cos(t)}{\sin^2(t)} \cdot \int_0^t e^{-\frac{\tau}{2}} d\tau \tag{5}$$

In the teaching process, teachers can feed back the data on students' energy consumption to students and parents. This helps students understand their physical fitness and progress and also helps parents understand their children's sports performance. According to the feedback results, teachers can adjust teaching methods and exercise intensity to better meet student's needs and improve the teaching effect. The energy detection process in physical education class is shown in Figure 3.

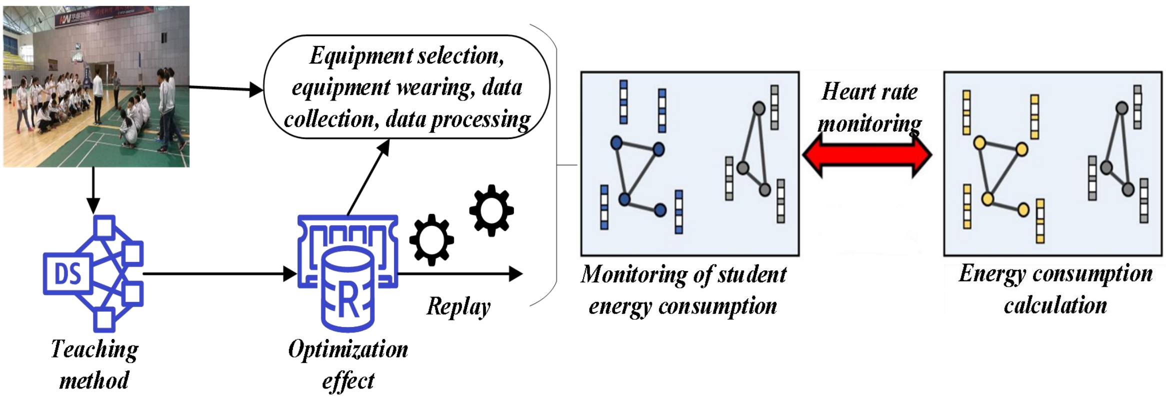

Figure 3. Flow Chart of Energy Detection

Through professional sports energy monitoring equipment and technical means, students' energy in physical education classes can be monitored and analyzed in real-time. This will help teachers better understand students' physical fitness and sports ability, adjust teaching methods and sports intensity, optimize teaching effect and improve students' learning experience.

B. Energy Consumption Optimization Method

By optimizing students' energy consumption, teachers can better control exercise intensity and teaching methods, avoid students' excessive fatigue or lack of exercise, and thus improve the teaching effect [28], [29]. Excessive exercise or insufficient exercise may affect students' health. Optimizing students' energy consumption can reduce unnecessary energy consumption, avoid students' injury due to excessive fatigue and protect students' health. Optimizing students' energy consumption can not only improve students' physical fitness, but also cultivate students' self-discipline and willpower, and promote students' all-round development [30].

The optimization method of energy consumption can be realized by the following steps in physical education:

Set reasonable sports goals: According to students' physical fitness and teaching goals, set reasonable sports goals. Avoid excessive or insufficient exercise to reduce unnecessary energy consumption. In this paper, the energy consumption is analyzed according to the total energy consumption formula, as shown in formula (6).

$$\Gamma(z)=\int_0^{\infty} t^{z-1}e^{-t}dt. \tag{6}$$

1. Optimize teaching methods: Adopt scientific teaching methods, such as staged training and intermittent training, so as to reduce students' energy consumption. At the same time, according to the students' physical condition and sports ability, adjust the teaching difficulty and intensity, and analyze the dynamic energy produced by biomass energy, to achieve better teaching effect. The formula is shown in formula (7).

$$\frac{\partial J(\theta)}{\partial \theta_j}=-\frac{1}{m}\sum_{i=0}^{m}(y^i-h_\theta(x^i))x_j^i \tag{7}$$

2. Reasonable arrangement of rest time: In the process of exercise, reasonable arrangement of rest time to avoid excessive fatigue of students. Taking breaks allows students to replenish their physical strength and decrease energy expenditure. Formula (8) illustrates the calculation method for athletes' energy consumption.

$$a=\begin{cases}\int x\mathrm{d}x\\ b^2\end{cases} \tag{8}$$

3. Adjust the sports environment: Adjust the sports environment according to weather, venues and other factors, such as choosing suitable sports venues and adjusting sports time, to reduce unnecessary energy consumption. The calculation formula for heat energy loss is shown in formula (9).

$$F_m=-\lim_{\hbar\to 0}\int_\rho \mathrm{F}_{\xi_\delta^L}^{\mathrm{C}_\delta^C}\left(A_\delta^h(s)\right) \tag{9}$$

4. Encourage students to adopt a balanced diet: A well-balanced diet aids in energy replenishment and reduction in energy consumption. Guide students to make sensible dietary choices, such as incorporating more high-protein and low-fat foods while avoiding excessive carbohydrate intake. Formula (10) depicts the relationship between heart rates and energy expenditure.

$$L:=\sum_{\mathrm{i}=0}^{n}\left(\ell_i\right)\ \pm\left(\partial\cdot\alpha_i\right)_{i\in G} \tag{10}$$

By implementing the aforementioned approaches, it becomes possible to optimize energy consumption during physical education, leading to improved teaching outcomes and enhanced physical fitness levels among students. Additionally, these strategies contribute to fostering students' awareness of energy conservation and environmental protection.

4. Experimental Design and Data Analysis

Experimental design and data analysis constitute pivotal components of scientific research and hold significant importance in implementing methods for optimizing energy consumption in students' physical education classes. The participants in this experiment include 5 physical education teachers and 100 students from a middle school. Both teachers and students possess a foundational understanding and skill set in physical education. To more intuitively show the working principle and performance of intelligent biomass energy systems, we have added detailed charts and flow charts to show the performance of intelligent biomass energy systems in actual operation.

A. Experimental Design

The purpose of this experiment is to explore the application effect of intelligent biomass energy in physical education and improve the teaching effect and efficiency through energy monitoring and consumption optimization. The subjects are PE teachers and students in a middle school. Before the study started, we fully considered potential ethical and safety issues and developed corresponding safety protocols. All participants were informed about the purpose, method of the study, and possible risks and signed informed consent. In addition, we worked closely with school PE teachers and safety personnel to ensure that all activities during the study process were conducted in a safe and controllable manner.

1. Experimental preparation: Select appropriate intelligent biomass energy equipment, such as a biomass gasifier, and install and debug it. At the same time, the measuring instruments and data acquisition system needed for the experiment are prepared.

2. Experimental Procedure: The students are categorized into two groups — the control group, receiving instruction through traditional physical education teaching methods; and the experimental group, utilizing intelligent biomass energy for physical education. Throughout the experiment, the energy consumption of both groups is monitored and recorded, with subsequent evaluation of the teaching effectiveness.

3. Data Processing and Analysis: Collected experimental data undergoes processing and analysis, facilitating a comparison of energy consumption and teaching effectiveness between the two student groups. Conclusions are drawn, and recommendations are proposed based on the results. Refer to Figure 4 for the experimental design flowchart.

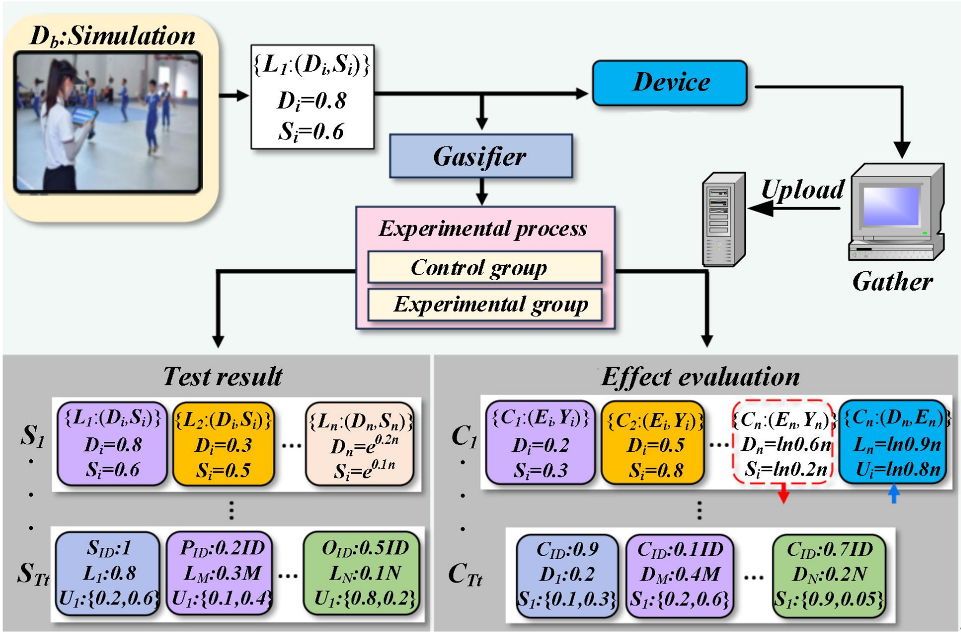

Figure 4. Experimental Design Flow Chart

Before the experiment, the intelligent biomass energy equipment is installed and calibrated to ensure its proper functioning. Concurrently, measuring instruments and a data acquisition system are prepared for the forthcoming experimental procedures. The students are then divided into two groups: the control group, undergoing traditional physical education teaching methods, and the experimental group, engaging in physical education with the use of intelligent biomass energy. Throughout the experiment, the energy consumption of both groups is closely monitored and recorded, and an assessment of the teaching effectiveness is conducted. The specific implementation steps are outlined as follows:

1. Control group: The traditional physical education teaching methods, that is, teachers lead students to carry out various sports activities, such as running, swimming, basketball and so on. In the process of activities, no intelligent biomass energy equipment is used.

2. Experimental group: Using intelligent biomass energy for physical education. In the process of activities, intelligent biomass energy equipment is used to provide students with heat energy or electric energy support. For example, in running activities, a biomass gasifier can be used to provide thermal energy support for students; In swimming activities, biomass liquefaction equipment can be used to provide electric energy support for students. The energy consumption analysis diagram of the two groups of students in different exercises is shown in Figure 5, and the nonlinear integral between exercise time and total energy consumption is shown in the formula (11).

$$E_{\text{time}} = k_{\text{time}} \cdot \int_0^t \sqrt{1+\cos(\tau)}\, d\tau \tag{11}$$

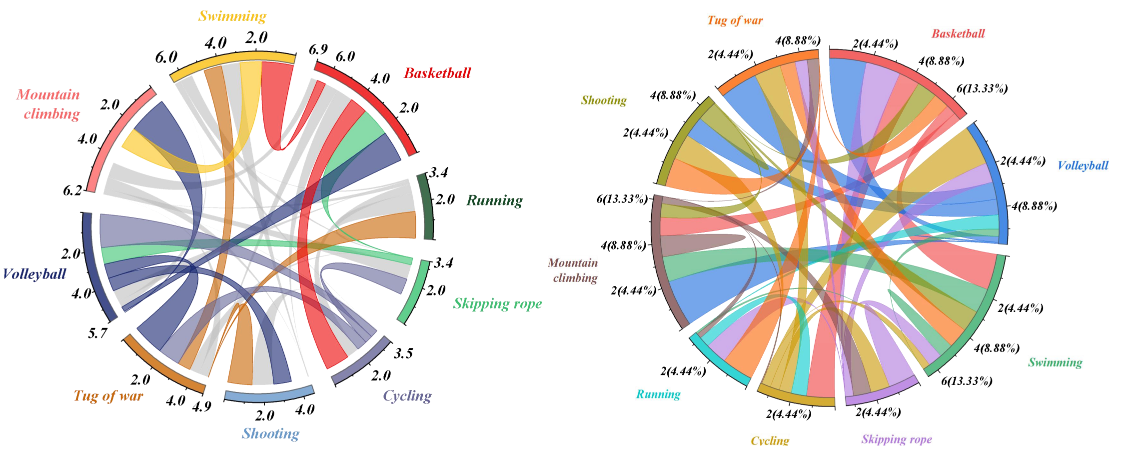

Figure 5. Analysis of Energy Expenditure of Two Groups of Students in Different Exercises

After the experiment, the collected data are processed and analyzed. Firstly, the energy consumption data of the two groups of students are compared and analyzed, including average energy consumption, maximum energy consumption and other indicators. At the same time, the teaching effect is evaluated, including students' physical fitness level, motor skills and other indicators. Upon comparing and analyzing the data from both groups, definitive conclusions are drawn, and corresponding recommendations are formulated.

To enhance readers' understanding of smart biomass energy technology, we provide complementary resources such as online interactive simulators and video tutorials. These resources detail the working principle, installation steps and operation methods of the intelligent biomass energy system, enabling the reader to have a more intuitive understanding of the practical application of this technology.

B. Data Analysis

This experiment is set up in the school gymnasium, using high-precision biosensors to monitor energy use, including power consumption, heat output, etc. At the same time, advanced energy monitoring tools are used to record data in real-time to ensure accuracy and real-time data.

Through the experiment, we collected data on energy consumption and the teaching effect of the two groups of students. After data processing and analysis, we get the following experimental results: the average energy expenditure of the students in the experimental group is 2000 joules/minute, while the average energy expenditure of the students in the control group is 2500 joules/minute. The energy consumption of students in the experimental group was notably lower than that observed in the control group. This underscores the effective reduction of students' energy consumption through the application of intelligent biomass energy in physical education. In addition to the basic descriptive statistics, we also conducted advanced statistical tests such as t-tests and analysis of variance, and the results showed that the application of smart biomass energy technology significantly reduces energy consumption in physical education. Refer to Figure 6 for an illustration of the relationship between energy consumption and teaching effectiveness in the two student groups.

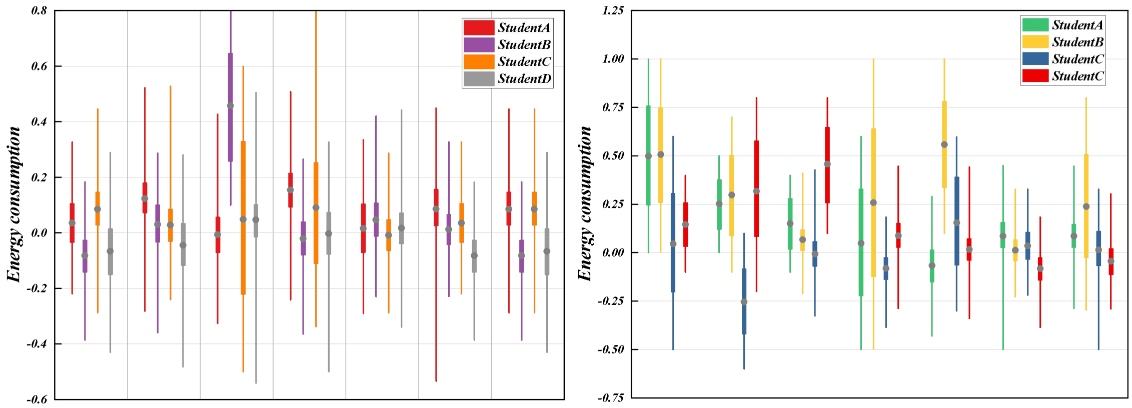

Figure 6. Relationship between Energy Expenditure and Teaching Effect of Two Groups of Students

Regarding physical fitness levels, students in the experimental group exhibited an average increase of 20%, surpassing the control group where the average increase was only 10%. Additionally, in terms of mastering motor skills, students in the experimental group acquired an average of one new skill, while their counterparts in the control group managed to master only 0.5 new skills. The application of intelligent biomass energy in physical education boosts students' fitness and motor skills. To assess its effectiveness, a control group without this technology was established. Analysis revealed that the group utilizing smart biomass technology showed a notable reduction in energy consumption. Figure 7 shows the physical changes of the two groups of students.

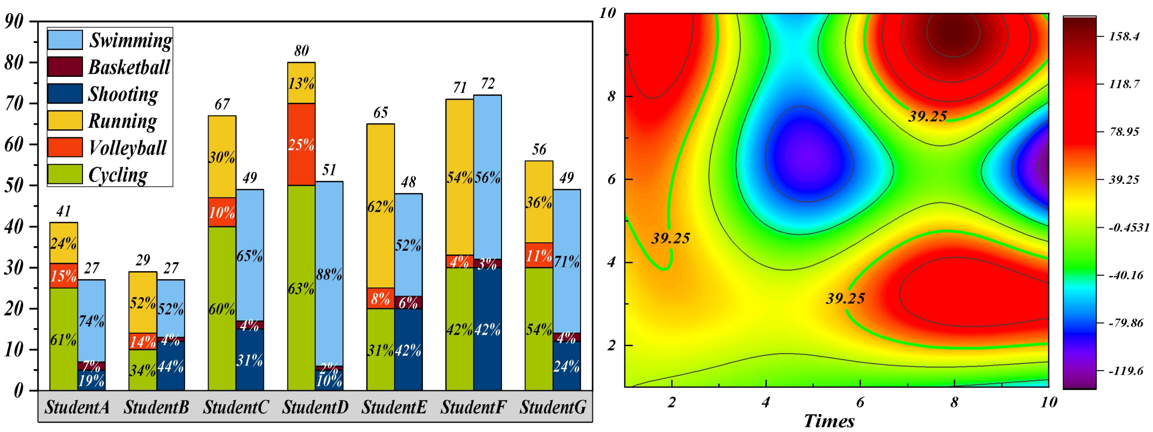

Figure 7. Physical Fitness Changes of the Students in the Two Groups

Based on the experimental results, intelligent biomass energy exhibits high potential in physical education. It provides sustainable energy support, meets teaching needs, and enhances teaching effect and efficiency through energy monitoring and consumption optimization. Heart rate variability over time is detailed in formula (12).

$$E_{HRV} = k_{HRV} \cdot \left(\frac{1}{\cosh(HRV)} - \frac{1}{\sinh(HRV)} \right) \quad (12)$$

This study offers novel insights for PE reform, highlighting the potential of renewable energy technologies like intelligent biomass energy to drive sustainable development and innovation. However, limitations like small sample size and short experimental duration necessitate future research with a larger scope and longer duration to comprehensively evaluate its application.

To harness the full potential of intelligent biomass energy in PE, interdisciplinary collaboration with renewable energy, sports science, and educational technology experts is needed. Joint research and practice can foster widespread adoption and sustainable development of this technology in physical education.

5. Conclusion

At present, there is relatively little research on the integration methods of life cycle assessment and life cycle cost analysis by scholars both domestically and internationally. Therefore, this article studies the integration of life cycle assessment and life cycle cost analysis and constructs a comprehensive evaluation model for the energy gasification and recycling system of traditional Chinese medicine residue based on the LCA and LCC integration methods. The model is applied to case analysis, and the main results of this study are summarized as follows:

1. Research on Integrated Methods of Life Cycle Assessment and Life Cycle Cost Analysis. This article systematically and comprehensively discusses the integration of LCA and LCC methods, identifies the necessity and differences of integrating the two analysis methods, and researches the integration methods of LCA and LCC. And construct a research framework for integrated analysis, using the Analytic Hierarchy Process and TOPSIS method for integrated analysis, in order to identify the optimal production process or optimal processing system of the product.

2. A comprehensive evaluation model for biomass energy gasification and recycling systems has been established. First, understand the process of biomass energy gasification and recycling, and divide it into three subsystems: biomass pretreatment system, gasification system, and gas utilization system; Secondly, the boundary of the research system is determined to be the entire lifecycle process from the production site of traditional Chinese medicine residue to gas utilization, as well as all factors related to energy, environment, and economy involved in the process, such as management and personnel. The data that may need to be collected for subsequent analysis is listed again, and the required data is combined with the process of biomass energy gasification and recycling system; Then, with comprehensive benefits as the target layer and energy resource consumption, environmental load, economy, and system efficiency as the criterion layer, the indicator structure is used. Based on the inventory data, the Analytic Hierarchy Process and TOPSIS method are used to quantitatively calculate the comprehensive benefits of the biomass energy gasification recycling system; Finally, a comprehensive analysis and evaluation will be conducted on the total score of the biomass gasification recycling system and its scores on various criteria and indicators.

3. Using a comprehensive evaluation model of biomass energy gasification and recycling system, taking a company in Henan Province as an example, a comprehensive comparative analysis was conducted between the traditional Chinese medicine residue landfill system and the medicine residue gasification and recycling system. This article first provides a detailed introduction to the traditional Chinese medicine residue treatment method of a pharmaceutical company in Shandong Province. Secondly, a list of data is collected and organized for future use. Then, the values of the two traditional Chinese medicine residue treatment systems on various indicators are calculated and compared. The results show that the traditional Chinese medicine residue gasification and recycling system uses more energy resources than the traditional Chinese medicine residue landfill system. However, the traditional Chinese medicine residue gasification and recycling system is significantly better than the traditional Chinese medicine residue landfill system in terms of environmental load and economy. Therefore, overall, the gasification and recycling system of traditional Chinese medicine residue has development advantages over the traditional Chinese medicine residue landfill system, which also proves that the biomass energy recycling system established in this article has strong practicality and scientificity.

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Research and demonstration application of key technologies of new base data center.

References

[1] C. Ammari, D. Belatrache, B. Touhami, and S. Makhloufi, “Sizing, optimization, control and energy management of hybrid renewable energy system - A review,” *Energy and Built Environment*, vol. 3, no. 4, pp. 399-411, May 2021, doi: 10.1016/j.enbenv.2021.04.002.

[2] O. Laayati, H. El Hadraoui, N. Guennoui, M. Bouzi, and A. Chebak, “Smart energy management system: Design of a smart grid test bench for educational purposes,” *Energies*, vol. 15, no. 7, p. 2702, Apr. 2022, doi: 10.3390/en15072702.

[3] N. Rane, “Contribution of ChatGPT and other generative Artificial Intelligence (AI) in renewable and sustainable energy,” *Social Science Research Network*, Jan. 2023, doi: 10.2139/ssrn.4597674.

[4] X. Li, “A model for analyzing teaching quality data of sports faculties based on particle swarm optimization neural network,” *Computational Intelligence and Neuroscience*, vol. 2022, pp. 1–11, Jun. 2022, doi: 10.1155/2022/6776603.

[5] S. Mousavi, G. Villarreal, M. H. Keshteli, and N. R. Smith, “Data-driven prediction and optimization toward net-zero and positive-energy buildings: A systematic review,” *Building and Environment*, vol. 242, pp. 110578–110578, Aug. 2023, doi: 10.1016/j.buildenv.2023.110578.

[6] T. Ahmad, R. Madonski, D. Zhang, C. Huang, and A. Mujeeb, “Data-driven probabilistic machine learning in sustainable smart energy/smart energy systems: Key developments, challenges, and future research opportunities in the context of smart grid paradigm,” *Renewable and Sustainable Energy Reviews*, vol. 160, p. 112128, May 2022, doi: 10.1016/j.rser.2022.112128.

[7] J. S. Jeong and D. González-Gómez, “A web-based tool framing a collective method for optimizing the location of a renewable energy facility and its possible application to sustainable STEM education,” *Journal of Cleaner Production*, vol. 251, p. 119747, Apr. 2020, doi: 10.1016/j.jclepro.2019.119747.

[8] M. Nutakki and S. Mandava, “Review on optimization techniques and role of artificial intelligence in home energy management systems,” *Engineering Applications of Artificial Intelligence*, vol. 119, p. 105721, Mar. 2023, doi: 10.1016/j.engappai.2022.105721.

[9] R. Tariq *et al.*, “Artificial intelligence assisted technoeconomic optimization scenarios of hybrid energy systems for water management of an isolated community,” *Sustainable Energy Technologies and Assessments*, vol. 48, p. 101561, Dec. 2021, doi: 10.1016/j.seta.2021.101561.

[10] Z. He, W. Guo, and P. Zhang, “Performance prediction, optimal design and operational control of thermal energy storage using artificial intelligence methods,” *Renewable and Sustainable Energy Reviews*, vol. 156, p. 111977, Mar. 2022, doi: 10.1016/j.rser.2021.111977.

[11] M. Thirunavukkarasu, Y. Sawle, and H. Lala, “A comprehensive review on optimization of hybrid renewable energy systems using various optimization techniques,” *Renewable and Sustainable Energy Reviews*, vol. 176, p. 113192, Apr. 2023, doi: 10.1016/j.rser.2023.113192.

[12] A. B. Kanase-Patil, A. P. Kaldate, S. D. Lokhande, H. Panchal, M. Suresh, and V. Priya, “A review of artificial intelligence-based optimization techniques for the sizing of integrated renewable energy systems in smart cities,” *Environmental Technology Reviews*, vol. 9, no. 1, pp. 111–136, Jan. 2020, doi: 10.1080/21622515.2020.1836035.

[13] E. L. V. Eriksson and E. M. A. Gray, “Optimization and integration of hybrid renewable energy hydrogen fuel cell energy systems – A critical review,” *Applied Energy*, vol. 202, pp. 348–364, Sep. 2017, doi: 10.1016/j.apenergy.2017.03.132.

[14] S. Ali, Z. Zheng, M. Aillerie, J. P. Sawicki, M. C. Péra, and D. Hissel, “A review of DC microgrid energy management systems dedicated to residential applications,” *Energies*, vol. 14, no. 14, p. 4308, Jul. 2021, doi: 10.3390/en14144308.

[15] F. Amalina *et al.*, “Blending big data analytics: Review on challenges and a recent study,” *IEEE Access*, vol. 8, pp. 1–1, 2019, doi: 10.1109/access.2019.2923270.

[16] V. Khare and P. Chaturvedi, “Design, control, reliability, economic and energy management of microgrid: A review,” *E-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 5, p. 100239, Sep. 2023, doi: 10.1016/j.prime.2023.100239.

[17] S. Habibi, O. Pons Valladares, and D. Peña, “New sustainability assessment model for Intelligent Façade Layers when applied to refurbish school buildings skins,” *Sustainable Energy Technologies and Assessments*, vol. 42, p. 100839, Dec. 2020, doi: 10.1016/j.seta.2020.100839.

[18] S. S. Ali and B. J. Choi, “State-of-the-art artificial intelligence techniques for distributed smart grids: A review,” *Electronics*, vol. 9, no. 6, p. 1030, Jun. 2020, doi: 10.3390/electronics9061030.

[19] G. S. Thirunavukkarasu, M. Seyedmahmoudian, E. Jamei, B. Horan, S. Mekhilef, and A. Stojcevski, “Role of optimization techniques in microgrid energy management systems—A review,” *Energy Strategy Reviews*, vol. 43, p. 100899, Sep. 2022, doi: 10.1016/j.esr.2022.100899.

[20] D. Jiang, W. Zhu, B. Muthu, and T. G. Seetharam, “Importance of implementing smart renewable energy system using heuristic neural decision support system,” *Sustainable Energy Technologies and Assessments*, vol. 45, p. 101185, Jun. 2021, doi: 10.1016/j.seta.2021.101185.

[21] P. Kotsampopoulos *et al.*, “Validating intelligent power and energy systems – A discussion of educational needs,” *Lecture Notes in Computer Science*, pp. 200–212, Jan. 2017, doi: 10.1007/978-3-319-64635-0_15.

[22] E. R. Arriola, A. T. Ubando, and W. Chen, “A bibliometric review on the application of fuzzy optimization to sustainable energy technologies,” *International Journal of Energy Research*, vol. 46, no. 1, pp. 6-27, Aug. 2020, doi: 10.1002/er.5729.

[23] D. Zhang *et al.*, “Reform of electrical engineering undergraduate teaching and the curriculum system in the context of the energy internet,” *Sustainability*, vol. 15, no. 6, pp. 5280–5280, Mar. 2023, doi: 10.3390/su15065280.

[24] P. Mishra and G. Singh, “Energy management systems in sustainable smart cities based on the internet of energy: A technical review,” *Energies*, vol. 16, no. 19, p. 6903, Jan. 2023, doi: 10.3390/en16196903.

[25] A. Padhy, S. Joshi, S. Bitragunta, V. Chamola, and B. Sikdar, “A survey of energy and spectrum harvesting technologies and protocols for next generation wireless networks,” *IEEE Access*, vol. 9, pp. 1737–1769, Jan. 2021, doi: 10.1109/access.2020.3046770.

[26] J. Krzywanski, “A general approach in optimization of heat exchangers by bio-inspired artificial intelligence methods,” *Energies*, vol. 12, no. 23, p. 4441, Nov. 2019, doi: 10.3390/en12234441.

[27] M. Shaterabadi, M. A. Jirdehi, N. Amiri, and S. Omidi, “Enhancement the economical and environmental aspects of plus-zero energy buildings integrated with INVELOX turbines,” *Renewable Energy*, vol. 153, pp. 1355–1367, Jun. 2020, doi: 10.1016/j.renene.2020.02.089.

[28] D. Song *et al.*, “A critical survey of integrated energy system: Summaries, methodologies and analysis,” *Energy Conversion and Management*, vol. 266, p. 115863, Aug. 2022, doi: 10.1016/j.enconman.2022.115863.

[29] S. Behera and N. B. Dev Choudhury, “A systematic review of energy management system based on various adaptive controllers with optimization algorithm on a smart microgrid,” *International Transactions on Electrical Energy Systems*, vol. 31, no. 12, Oct. 2021, doi: 10.1002/2050-7038.13132.

[30] W. Drożdż, Y. Bilan, M. Rabe, D. Streimikiene, and B. Pilecki, “Optimizing biomass energy production at the municipal level to move to low-carbon energy,” *Sustainable Cities and Society*, vol. 76, p. 103417, Jan. 2022, doi: 10.1016/j.scs.2021.103417.