Examining and prioritizing the effect of sustainable energy on the job market to advance China's green workforce

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A B S T R A C T

China, the world's greatest emitter of greenhouse gases, has committed to reaching peak carbon dioxide emissions by 2030 and carbon neutrality by 2060. One strategy to accomplish this aim is switching to a low-carbon economy via advancing renewable energy (RE) projects. Therefore, this study focuses on solar, wind, biomass, and hydropower and examines the beneficial employment effects of RE projects in China. The study uses fuzzy-based Multi-Criteria Decision Making (MCDM) methodologies, such as the Analytical Hierarchy Process (AHP) and Weighted Aggregated Sum Product Assessment (WASPAS), to evaluate numerous employment effect criteria and sub-criteria. Based on these evaluations, the report prioritizes four main types of RE projects. According to the fuzzy AHP technique results, direct employment, skill requirements, and local employment are the most crucial employment effect factors. The study then employed the fuzzy WASPAS approach to assessing various RE initiatives' employment prospects. According to the findings, hydropower is the best choice for creating jobs, followed by wind and solar power initiatives. In recent years, the hydro, wind, and solar power industries have experienced rapid expansion, creating numerous job possibilities in production, installation, operation, and maintenance. Additionally, creating RE projects can boost regional economic growth and lessen poverty.

1. Introduction

China has set lofty goals to reach peak carbon dioxide emissions by 2030 and carbon neutrality by 2060 in order to lessen the effects of climate change [1]. Considerable shift towards a low-carbon economy will be necessary to achieve these goals, with the growth of renewable energy (RE) projects playing a crucial role. China has made great progress in the past few years toward a low-carbon economy, with an emphasis on RE in particular.

China is now the world's top producer of RE due to an increase in production. This increase has been influenced by a variety of issues, including concerns over environmental degradation, energy security, and economic expansion. China's commitment to RE is demonstrated by a number of significant programs and goals. In 2016, the country published its 13th Five-Year Plan, which included a target to generate 20 % of the country's energy from renewable sources by 2030 [2]. The country has developed a number of laws and

incentives to assist the expansion of RE. They include subsidies for RE projects, tax breaks for RE businesses, and feed-in tariffs for solar and wind energy [3]. Also, a number of financing avenues have been established by the government to assist RE research and development. China's RE industry has expanded significantly as a result of these regulations and incentives. The country's installed solar, wind, and hydropower capacity reached 895 GW in 2020, accounting for 31 % of the world's RE capacity [4]. With approximately 5 million individuals employed in the RE industry in China, the sector's expansion has also greatly increased employment prospects.

Over the years, hydropower projects in China have significantly contributed to the growth of the labor force. Due to its plentiful water resources, the country has a long history of investing in the development of hydropower, and these projects have resulted in the creation of jobs across various industries. A sizable workforce is needed such as engineers, project managers, skilled and unskilled laborers, and support employees. large-scale initiatives. A hydropower project must be continuously operated and maintained after it is completed. This covers the technical, engineering, and support positions necessary to guarantee the plant's effective and secure operation. China has been spending funding on RE technology-related research and development. This has created job possibilities in research organizations, academic institutions, and commercial businesses that are concerned with enhancing the sustainability.

Solar energy is one industry where RE initiatives have the potential to generate employment [5]. China has already risen to the top of the solar panel manufacturing world, and it has big goals for expanding its solar energy production. Many jobs, including those in manufacture, installation, maintenance, and research and development, may be generated by the expansion of solar projects. The field of wind energy is another location for RE projects [6]. Some of the biggest wind farms in the world are located in China, which has already emerged as a global leader in wind turbine production. Employment opportunities in industries including manufacturing, installation, maintenance, and operation may result from the development of new wind farms. Moreover, China offers prospects for the growth of projects utilizing geothermal, biomass, and hydropower. Jobs can be created by these kinds of initiatives in a number of industries, including engineering, building, and operations. It's crucial to give local recruiting and training initiatives top priority if you want to guarantee that RE projects have beneficial job consequences. This can ensure that local people have the skills they need to succeed in the RE business and that jobs are produced in the communities where projects are located [7]. Also, it is crucial to guarantee that employees receive fair compensation and work in secure environments.

Nevertheless, multi-criteria decision making (MCDM) is one of the important approach that has gained popularity recently. This method can offer an organized and methodical method for evaluating employment consequences and can assist in accounting for uncertainties and subjective preferences in the decision-making process [8]. This study used fuzzy based MCDM approaches, such as the fuzzy Analytical Hierarchy Process (AHP) and fuzzy Weighted Aggregated Sum Product Assessment (WASPAS), to evaluate and rank the employment impacts criteria, sub-criteria, and different types of RE projects, such as wind power projects, solar power projects, hydropower projects, and biomass power projects. Here are streamlined objectives for the study.

- To assess and prioritize the employment impacts criteria and sub-criteria of different RE projects in China using Fuzzy AHP method.
- To prioritize the effects on employment of RE projects in China using Fuzzy WASPAS method.
- To determine which RE projects are most likely to contribute to China's job market to advance green workforce as it transitions to a low-carbon economy.

Table 1
Previous studies relating to employment impacts in RE projects.

Study theme	Findings	Country	Reference
Driving force of rising RE in China	The findings showed that regulations positively and significantly affect RE development. Employment's impact on RE declines with income, according to the study.	China	[10]
Assessing the Employment Impact of RE Targets for Electricity Generation by 2020	The study examined how government support for RE power sources affects employment, it also assessed RE goals' employment effects from 2008 through 2020.	Portugal	[11]
Examining the Employment Impacts of Power Generation in Renewable-Based Energy Systems	The analysis found that biomass and solar photovoltaic power facilities in rural areas may generate 350 TWh by 2030. Over 45 years, rural power generation jobs might increase by 2.28 million person-years.	Japan	[12]
Economic and employment impacts of offshore wind	The research showed that developing 2.5–4.5 GW of offshore wind power in Ireland by 2030 may generate €763 million to €1.4 billion in gross value added and 11,424 to 20,563 supply chain jobs.	Ireland	[13]
Employment creation related to renewables expansion	According to study, a low-carbon economy would create 200,000 energy sector jobs. These direct RE sector jobs would make about 1 % of the EU's workforce in 2050.	Europe	[14]
Employment impacts of solar energy	The results anticipated the economy's direct and indirect employment consequences. The findings indicate that Turkey will rely heavily on solar energy.	Turkey	[15]
Job creation in renewable power technologies	The study estimated that RE technologies might provide 1.04 to 5.04 person-years of employment per GWh over their lifetime. Each technology also affects the amount and types of jobs created throughout industrial sectors over its lifespan.	–	[16]
RE policies and its impact on employment	The findings demonstrated that 1 TW h of solar PV and wind power will create 45.1 thousand direct and 15.8 thousand indirect employment.	China	[5]
Employment impacts in renewable and new energy	The findings revealed that RE development might create 7 million jobs between 2011 and 2020. Only 81.8 % of these potential job increases can be realized due to mismatch.	China	[17]

These objectives center on the study's main goal of assessing and ranking China's RE projects' employment impacts. Therefore, taking into account the established criteria, a ranking of the RE projects is created based on their employment impacts. Ultimately, the study makes a substantial contribution by providing a data-driven method for identifying which RE projects have the most potential to support China's job market and further the country's shift to a low-carbon, green economy. The trajectory of China's sustainable development initiatives can be significantly shaped by this evidence-based decision-making, which will balance environmental sustainability and economic growth.

2. Literature review

In China, RE is a key component of the country's electricity generation. To attain 20 % of the nation's energy mix by 2030, the Chinese government has set ambitious goals for the deployment of RE [9]. The switch to RE could lead to a considerable increase in job possibilities in China, especially in the construction of RE infrastructure. The possible employment consequences of RE projects were reviewed and studied in the many existing research. The prior research studies found through a literature study are shown in Table 1.

Investment in RE sources in Italy has the potential to create jobs as the EU decarbonizes [18]. The study evaluates RE sources investments, specifically Italy's PNIEC plan's wind, photovoltaic, hydropower, and geothermal projects, using Input-Output analysis. The analysis shows that RE sources investments can boost the Italian economy directly and indirectly through creating jobs. Besides, another study revealed that renewable energy, notably solar and wind, has created U.S. jobs. The salary premium for green jobs is considerably higher for those needing less education [19]. These occupations commonly appear in fossil fuel extraction areas, providing a transition path for populations affected by the energy sector's collapse. Moreover, South Korea's sustainable energy

Table 2
Employment impacts criteria for various RE projects.

Criteria	Sub-criteria	Summary	Reference
Direct Employment (EIC1)	Number of jobs created per MW of installed capacity (EIC11)	It refers to the amount of employment directly created per MW of installed capacity. It shows the amount of labor necessary to construct, operate, and maintain the RE project.	[5,14]
	Number of jobs created per project (EIC12)	It indicates the number of jobs directly produced by the RE project. It offers a comprehensive evaluation of the project's employment impact.	[14,23]
	Types of jobs created in direct employment (EIC13)	It refers to the several job categories that the RE project has established, including construction, operation, and maintenance. It details both the potential for local employment development and the variety of skills and expertise needed for the project.	[23,24]
Indirect Employment (EIC2)	Number of jobs created in the supply chain (EIC21)	The number of employment generated in the supply chain indirectly, such as in manufacturing and transportation, is measured by this sub-criterion. It offers details on how the RE project's employment effects extend beyond direct employment.	[25,26]
	Number of jobs created in related industries (EIC22)	The number of employment generated indirectly in allied sectors like services and construction is the subject of this sub-criteria. It gives details on how the RE project might help local communities develop their jobs.	[25,27]
	Types of jobs created in indirect employment (EIC23)	Many different job types, including production manager, marketing analyst, and human resource, can be formed through indirect employment.	[5,27]
Local Employment (EIC3)	Percentage of local workers employed (EIC31)	The proportion of local residents employed by the RE project is measured by this sub-criterion. It gives details on how the project would affect local jobs and economic growth.	[24]
	Local hiring policies and practices (EIC32)	The policies and procedures used by the RE project to employ locals and acquire goods and services locally are covered under this sub-criterion. It reveals the project's dedication to supporting regional economic growth.	[5,28]
	Sustainability of employment over the project lifetime (EIC33)	The sustainability of job possibilities generated by the RE project over its lifetime is the subject of this sub-criteria. It details the possibility that the project may offer secure and dependable work opportunities.	[27]
Skill Requirements (EIC4)	Level of skill required for different types of jobs (EIC41)	The level of expertise necessary for various job kinds established by the RE project is discussed in this sub-criteria. It details the possibility that the project will create high-skilled employment opportunities.	[12,29]
	Availability of skilled workers in the local labor market (EIC42)	The availability of skilled workers to fill the employment openings caused by the RE project is the subject of this sub-criteria. It offers details on the likelihood that the project will draw in and keep talented workers in the neighborhood.	[12]
	Opportunities for skills development and career advancement (EIC43)	The possibility that the RE project will give employees the chance to progress their careers and learn new skills is covered by this sub-criterion. It gives details about the project's ability to aid in the workforce's professional development.	[30]
Wage Levels (EIC5)	Average wage levels for different types of jobs (EIC51)	The typical pay rates for various job categories established by the RE project are discussed in this sub-criteria. It offers details on the amount of compensation received by project employees.	[31,32]
	Wage levels compared to other industries in the region (EIC52)	In regard to other local industries, this sub-criterion compares the pay scales for employees working on the RE project. It offers details on how competitive the RE industry is in hiring.	[32,33]
	Average wage levels in supply chain jobs (EIC53)	This sub-criterion refers to the average wage levels for supply chain related jobs created by the RE project.	[33]

development is outlined in four scenarios, from business-*as*-usual to visionary change [20]. RE and lower energy demand boost security, create power producing jobs, and reduce greenhouse gas emissions. Agro-processing and tourism are highlighted to address Ghana's jobless growth [21]. With favorable rules and export possibilities, these places will bring many jobs and economic growth. To prosper, these industries must overcome skill gaps and other obstacles, according to the report. This Africa-adapted study shows that energy efficiency and RE create jobs and become more cost-effective as adoption increases [22]. Additional studies from various nations or regions shed light on RE projects and policies' employment effects. They clarify how RE may boost global economic growth and employment creation.

These studies have shed important light on the potential effects of RE programs on job creation, economic expansion, and sustainable development. The discourse has been affected by continuing discussions and recent developments in the area of how RE project employment impacts. The question of whether the emphasis should be on increasing the amount of jobs created or on improving the caliber of employment prospects produced by RE projects is one that is receiving more attention. In this regard, there are still research gaps that need to be filled despite the expanding body of literature on the employment impacts of RE projects. The lack of use of quantitative methodologies to evaluate how RE projects in China will affect employment is a research gap. Hence, more thorough and methodological techniques are required that can take into consideration the complexity and unpredictability of the employment consequences of RE projects. These gaps in the literature are addressed by this study, which use the fuzzy AHP and fuzzy WASPAS methodologies to assess and rank the employment impacts criteria, sub-criteria, and various types of RE projects in China. This approach can assist in identifying the most effective and durable RE projects for the generation of jobs in China by including subjective judgments and preferences, addressing uncertainties, and inaccurate data.

3. The employment impacts to renewable energy projects development

3.1. Employment impacts criteria and sub-criteria

This study will apply a fuzzy MCDM approach to evaluate how different types of RE projects will affect employment in China. The following criteria and sub-criteria are used to evaluate how RE projects would affect employment. The most significant job impacts criteria and sub-criteria from the literature are shown in Table 2.

These criteria and sub-criteria will be used to assess the employment impacts of different types of RE projects in China, and to identify the most sustainable and beneficial projects for employment creation in the sector.

3.2. Employment impacts in various types of renewable energy projects

RE projects are those that generate energy from renewable sources such as wind, solar, hydropower, and biomass [34]. These sources of energy produce little to no greenhouse gas emissions, are sustainable, and have lower operating costs [35]. However, in some parts of Europe, operating costs remain a significant problem for RE plants [36]. RE projects not only have significant environmental benefits, but also create employment opportunities, poverty reduction, and enhance economic development. The aim of this study is to evaluate and rank RE project alternatives based on their performance against the stated employment impact criteria and sub-criteria. Decision-makers can choose the approach that best serves local communities by analyzing employment impacts.

3.2.1. Employment impacts in various types of renewable energy projects

RE projects are those that generate energy from renewable sources such as wind, solar, hydropower, and biomass [34]. These sources of energy produce little to no greenhouse gas emissions, are sustainable, and have lower operating costs. RE projects not only have significant environmental benefits, but also create employment opportunities, poverty reduction, and enhance economic development. In this context, the Fuzzy AHP and Fuzzy WASPAS will be used to evaluate and rank different project alternatives based on their performance against the identified employment impact criteria and sub-criteria. By comparing the employment impacts of each alternative, decision-makers can identify the option that provides the greatest overall benefits to local communities while considering other factors as well. In the following sub-sections, we describe the potential RE projects options in China.

3.2.2. Hydropower project

China has the largest installed capacity of hydropower in the world, and the hydropower sector has played a significant role in meeting the country's energy demands [37]. The construction of hydropower projects creates a significant number of employment opportunities, particularly in the areas of engineering, construction, and project management. According to the International Hydropower Association, the construction of the Three Gorges Dam in China created over 60,000 jobs [38]. The operation and maintenance of hydropower projects is also a significant source of employment in China. According to the National Energy Administration (NEA), the operation and maintenance of hydropower projects employed around 80,000 people in China in 2020 [9]. Employment opportunities in logistics and transportation, the production of steel and concrete, and engineering and consulting services may also arise as a result of the growth of hydropower projects. It is important to note that hydropower projects have substantial negative social and environmental effects, particularly when it comes to displacing and upsetting nearby residents and ecosystems. Therefore, it is crucial to thoroughly consider the potential implications of hydropower projects and make sure that the right steps are taken to prevent any adverse effects.

3.2.3. Solar power project

In China, solar energy projects have a large impact on employment in terms of both job generation and skill development. China now produces about half of the world's solar panels, demonstrating the country's recent tremendous growth in the solar energy industry [39]. Through the manufacture, installation, operation, and maintenance phases of solar power project lifespan, this increase has generated a sizable number of employment possibilities. Around 3 million people were employed in China by the solar industry, with the majority of these positions being in manufacturing, according to report of IRENA [40]. Significant employment opportunities are also generated by the installation of solar panels.

3.2.4. Wind power project

China has the largest installed capacity of wind power in the world. The manufacturing of wind turbines and related components in China has created a large number of jobs. The installation of wind turbines creates significant employment opportunities. According to the NEA, the installation of 10 GW of wind power in China created around 170,000 jobs [41]. According to the Global Wind Energy Council, the wind power sector employs around 52,000 people in operation and maintenance roles [42]. In addition to these direct employment impacts, wind power projects also have indirect employment impacts, particularly in the supply chain and related industries.

3.2.5. Biomass power project

Biomass power projects are those which generate electricity from organic materials like crop residues, wood waste, and animal manure [43]. In China, the biomass power sector is relatively small compared to other RE sectors like solar, wind, and hydropower, but it has been growing in recent years. The collection and processing of biomass materials creates employment opportunities in rural areas, particularly for farmers and agricultural workers. Some 260,000 people were employed in China's biomass industry, the majority of whom worked in the collection and processing of biomass, according to a report by the International Renewable Energy Agency [44]. The sustainability of biomass power plants should be taken into consideration, especially if biomass materials are not gathered and processed in a sustainable way. The possible effects of biomass power plants must therefore be carefully considered, and the necessary steps must be taken to assure their sustainability.

4. Methodology

This study evaluated the effects on employment and ranked the RE projects depending on how well they performed at creating jobs using the fuzzy AHP and fuzzy WASPAS approaches. The methodology offers a framework for evaluating the employment effects of RE projects in China using fuzzy MCDM methods, which can aid in directing investment and policy choices. Fig. 1 displays the
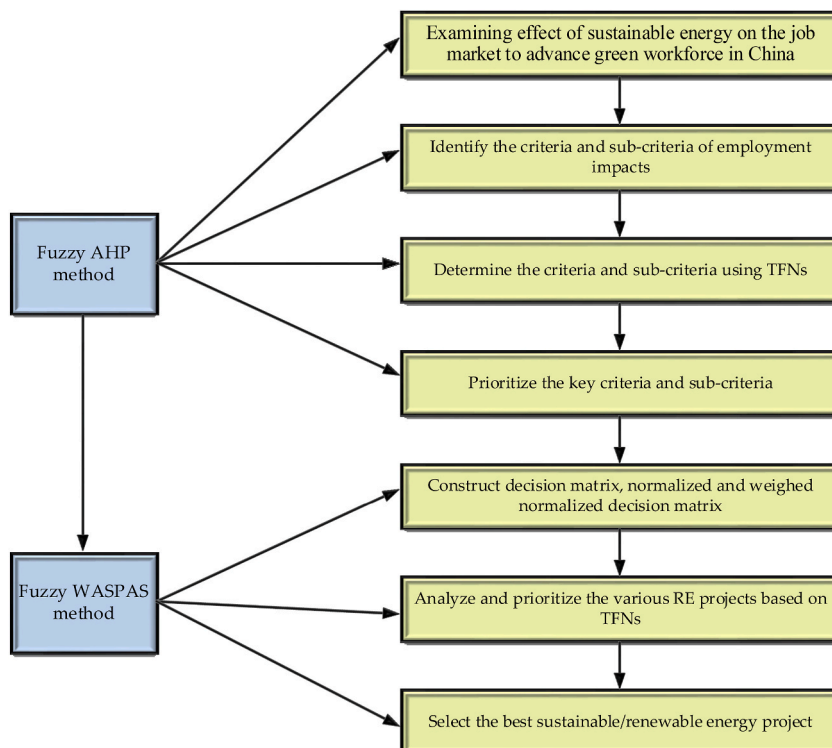

Fig. 1. Methodology of this study.

methodology of current research.

4.1. The fuzzy AHP method

The AHP was developed by Saaty in 1970s [45]. This research extends the traditional method into fuzzy logic to form fuzzy AHP. This approach allows for the consideration of uncertainty and imprecision [46,47]. The fuzzy AHP may deal with ambiguous or imprecise information, such as language expressions or personal beliefs, which may not be measurable using regular AHP. Table 3 depicts the Triangular Fuzzy Numbers (TFNs) scale based on linguistic variables.

Step I.   Triangular fuzzy matrix (TFM):

$$X_i = (l_i, m_i, u_i) \tag{1}$$

After, the TFM is created with the middle TFM:

$$X_m = \left[x_{ijm} \right] \tag{2}$$

Step II.   Create and compute the weight vector and lambda max:

Step III.   Create consistency index (CI):

$$CI_m = \frac{\lambda_{max}^m - n}{n-1} \tag{3}$$

$$CI_g = \frac{\lambda_{max}^g - n}{n-1} \tag{4}$$

Step IV.   Create the consistency ratio (CR):

$$CR_m = \frac{CI_m}{RI_m} \tag{5}$$

$$CR_g = \frac{CI_g}{RI_g} \tag{6}$$

4.2. The fuzzy WASPAS method

The WASPAS method was proposed by Zavadskas [49]. This study utilized fuzzy based WASPAS method to incorporates the fuzzy logic to account for imprecision and uncertainty in the process. A fuzzy WASPAS decision-making process aggregates the weighted sum and product of the choice criteria [50,51]. fuzzy WASPAS is a versatile approach to decision-making that may be used in various contexts, including social, economic, and environmental ones. The linguistic variables matching TFNs is given in Table 4.

Step I. Construct a fuzzy decision matrix:

$$\widetilde{A} = \begin{bmatrix} \widetilde{a}_{11} & \cdots & \widetilde{a}_{1j} & \cdots & \widetilde{a}_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \widetilde{a}_{i1} & \cdots & \widetilde{a}_{ij} & \cdots & \widetilde{a}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \widetilde{a}_{m1} & \cdots & \widetilde{a}_{mj} & \cdots & \widetilde{a}_{mn} \end{bmatrix} \text{Here } i = 1, \ldots, m \text{ and } j = 1, \ldots, n \tag{7}$$

Step II. Determining the integrated utility function value for an alternative:

Table 3
TFNs scale.

Code	Linguistic variable	TFNs
1	Equally preference	(1,1,1)
2	Weak preference	(0.5,1,1.5)
3	Strong preference	(1.5,2,2.5)
4	Very strong preference	(2.5,3,3.5)
5	Extremely strong preference	(3.5,4,4.5)

The fuzzy AHP method involves following several steps [48].

Table 4
The TFNs scale based on linguistic variables.

Code	Linguistic scale	TFNs
1	Very poor	(0,0,1)
2	Poor	(0,1,3)
3	Medium poor	(1,3,5)
4	Fair	(3,5,7)
5	Good	(5,7,9)
6	Very Good	(7,9,10)
7	Extreme	(9,10,10)

The main steps in fuzzy WASPAS method are as follows [52].

$$K_i = \lambda \sum_{j=1}^{m} X_i + (1 - \lambda) \sum_{j=1}^{m} Y_i, \lambda = 0, ..., 1, 0 \leq K_i \leq 1 \tag{8}$$

here, λ is based on the assumptions.

$$\lambda = \frac{\sum_{i=1}^{m} Y_i}{\sum_{i=1}^{m} X_i + \sum_{i=1}^{m} Y_i} \tag{9}$$

Step III. Ranking the alternative preference order and select with maximal K_i value.

In the study, five professional and experienced experts from different fields of study were consulted to examine this multi-faceted decision-making problem. The group comprised a nine-year-experienced research analyst, an associate professor with eight years of academic experience, a stakeholder representative with eleven years of insights, an experienced economist with twelve years in the field, and an expert in RE with eight years of experience. Collectively, these specialists provided a thorough analysis of this complex subject of decision-making. Comprehensive details regarding these specialists are available in the supplementary file, which insights into their backgrounds, ages, and associations. These experts were consulted to provide the meaningful insights to the employments impacts (criteria and sub-criteria) into different type of RE projects. After being contacted through email, each expert was requested to fill out the questionnaire and share their insightful opinions on the topic. This approach made it possible to gather their knowledge and viewpoints for the study in a practical and effective way. Thus, a diverse group of experts from various fields can provide valuable insights into the employment impacts of RE projects in China and help ensure a comprehensive and accurate assessment.

5. Results and discussion

This study adopted the fuzzy AHP and fuzzy WASPAS methods to assess the employments impacts criteria and sub-criteria of different types of RE projects in China. The fuzzy AHP method has been used to evaluate and rank the employment impacts criteria and sub-criteria. While the fuzzy WASPAS method has been used to rank the RE projects based on the findings of fuzzy AHP.

5.1. Results of employment impacts criteria using fuzzy AHP

This section provides the findings of employment impacts criteria using fuzzy AHP method. The results indicate that direct employment (EIC1) is the most suitable criteria, with a weight of 0.252. The high ranking of this criterion shows that RE projects provide jobs, which are crucial to economic growth and social well-being. The skills requirements (EIC4) is categorized as second significant criteria with a weight of 0.216. It demonstrates the skills and qualifications needed for RE project workers. As the RE industry grows, workforce development and education initiatives are needed to educate the workforce with appropriate skills. The local employment (EIC3) is considered as third crucial employment impact criteria with a weight of 0.194. The economy is boosted by local employment, which also promotes a sense of community and ownership. It reduces the need for external labor and improves the capabilities of the local workforce. The indirect employment (EIC2) and wages level (EIC5) are ranked as lowest important criteria for

Table 5
Results of main criteria of employment impacts.

Code	Employment impacts criteria	Weight	Rank
EIC1	Direct employment	0.252	1
EIC4	Skill requirements	0.216	2
EIC3	Local employment	0.194	3
EIC2	Indirect employment	0.172	4
EIC5	Wage levels	0.156	5

Policymakers and stakeholders should prioritize job creation, worker skills, and community engagement while developing RE projects to ensure a sustainable and prosperous future.

the employment impacts in various RE projects in China. EIC2 comprises employment generated by RE project-related supply chain activities or in supporting industries. The EIC5 criterion pertains with the wages and income levels of those employed on RE projects. The analysis shows that all identified employments criteria are very useful for RE projects. Table 5 presents the weighs and ranking of employments impacts criteria.

5.2. Results of employment impacts sub-criteria using fuzzy AHP

Also, this study presents the results of the sub-criteria for employment implications in relation to each primary criterion. The findings indicate that with a weight of 0.393, the number of jobs produced per project (EIC12) is ranked as the most significant employment impacts sub-criteria. This measures the project's immediate employment generation capabilities, making it a key sub-criterion for assessing economic benefits and job creation. The second crucial sub-criteria, with a weight of 0.331, is the number of employment generated per MW of installed capacity (EIC11). Employment generation efficiency compared to RE project capacity indicates how well a project uses its potential to produce jobs. This sub-criterion is crucial for assessing the project's job generation per unit of energy generated. The employment types generated (EIC13) is regarded as the least significant sub-criteria that affects the progress of the project. EIC13 shows the types of jobs available within RE projects, such as those associated with the building industry, operations, maintenance, and support roles. The weights and rankings of the employment impacts sub-criteria are shown in Fig. 2.

The weights and rankings of the employment impacts sub-criteria linked to the indirect employment criteria (EIC2) are shown in Fig. 3. The outcomes demonstrate that the number of jobs created in related industries (EIC22) has attained the maximum importance with a weight of 0.387. It represents the number of jobs created in RE project-related industries such manufacturing, component production, and support services. This sub-criterion emphasizes RE projects' economic ripple effect and ability to create jobs. With a weight of 0.341, the number of jobs produced in the supply chain (EIC21) has been evaluated as the second most important employment impacts sub-criteria. EIC21 shows how RE projects are integrated with numerous economic sectors and can promote supply chain employment development. The employment sub-criteria for RE projects that is least essential is the sorts of jobs created (EIC23).

The weights and rankings of the sub-criteria related to the local employment criteria (EIC3) is shown in Fig. 4. The results demonstrate that the sustainability of employment over the course of the project (EIC33), which has a weight of 0.383, is the most appropriate sub-criteria. Long-term job opportunities help local communities thrive, making this sub-criterion crucial to assessing RE projects' social and economic advantages. With a weight of 0.331, the local hiring policies and practices (EIC32) are evaluated as the second-most crucial sub-criteria. It emphasizes the importance of hiring and engaging local workers to ensure community members have access to project-created jobs. Local hiring policies and practices build community and ownership. Whereas EIC31, which measures the employment rate of locals, has the lowest weight of 0.285. It sheds light on the project's connection with the local workforce, but employment sustainability and local hiring policies are more significant. It remains a key component in assessing the project's local impact.

The weights and rankings of the sub-criteria for the skills requirement criteria EIC4) is given in Fig. 5. The results indicate that the most crucial sub-criteria, with a weight of 0.368, is the degree of expertise necessary for various types of occupations (EIC41). It emphasizes the need of understanding project job roles' knowledge and capabilities. personnel planning and development require this information to ensure that the RE project's personnel possesses the skills and knowledge to perform various jobs. With a weight of 0.335, the opportunities for skill development and career progression (EIC43) are regarded as the second important sub-criteria. RE projects are crucial for employment creation, skill development, and professional progress. This sub-criterion recognizes RE projects' long-term influence on trained and adaptive workforces. The third most important employment effect criterion, with a weight of 0.296, is the accessibility of skilled employees on the local labor market (EIC42). within the local labor market, showing how easily RE projects may hire experienced workers. Although not the most important sub-criteria, it helps determine if project operations can source skilled workers.

The weights and rankings of the employment impacts sub-criteria in relation to the wage levels (ECI5) criteria is presented in Fig. 6. The findings show that the top rank sub-criteria (EIC51), with a weight of 0.380, is the average wage levels for various job kinds. This metric sheds light on how the project's workers is paid, enabling assessment of the project's contribution to raising the economic well-being of its workers. With a weight of 0.347, the average wage rates for supply chain jobs (EIC53) are the second most important sub-
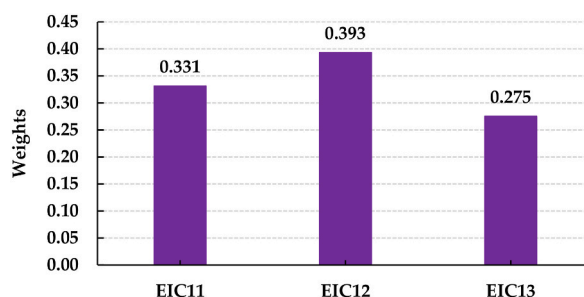

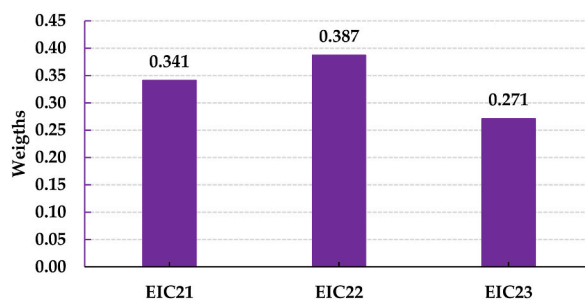**Fig. 2.** The Ranking of sub-criteria with respect to direct employment criteria (EIC1).

Fig. 3. The Ranking of sub-criteria with respect to indirect employment criteria (EIC2).
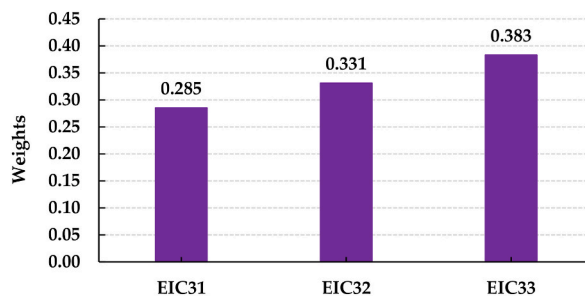

Fig. 4. The Ranking of sub-criteria with respect to local employment criteria (EIC3).
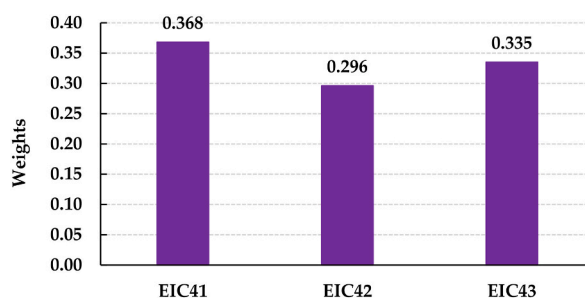

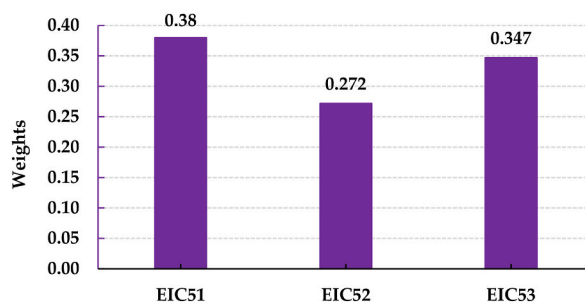**Fig. 5.** The Ranking of sub-criteria with respect to skills requirement criteria (EIC4).

Fig. 6. The Ranking of sub-criteria with respect to wage levels criteria (EIC5).

criteria. This sub-criterion emphasizes how the project's economic impact extends beyond its immediate workforce to include a larger network of firms and workers who are a part of its supply chain. The third rank sub-criteria with a weight of 0.272 is the wage levels in relation to other industries in the area (EIC52). As a result, this criterion assesses the amount of earnings a RE project pays its employees.

These comprehensive sets of sub-criteria show the impacts of RE projects in China, and the fuzzy AHP methodology allows for the

integration of qualitative and quantitative data to make a well-informed decision on the most suitable RE project based on the employment impacts.

5.3. Results of overall employment impacts sub-criteria

This study established fifteen evaluation sub-criteria. These sub-criteria were calculated by multiplying the final weight by each major criterion and its sub-criteria weight. Table 6 shows the final sub-criteria ranking. The results show that the most appropriate sub-criteria, which may have a potential employment impact on RE projects, is the number of jobs produced per project (EIC12). The number of jobs created per MW of installed capacity (EIC11), level of skill required for different types of jobs (EIC41), sustainability of employment over the project lifetime (EIC33) are the next significant sub-criteria for the sustainable development of the project. Moreover, the remaining employment impacts sub-criteria are ranked as follows: The remaining green innovation sub-criteria are prioritized as follows: EIC43 < EIC13 < EIC22 < EIC32 < EIC42 < EIC51 < EIC21 < EIC31 < EIC53 < EIC52 < EIC23.

The fuzzy AHP methodology provides a robust approach to evaluating the employment impacts of RE projects in China. The results can inform policymakers and stakeholders about the potential employment impacts of RE projects and help to identify the most promising alternatives.

5.4. Results of multiple RE projects using fuzzy WASPAS method

The results of the fuzzy WASPAS MCDM analysis indicate that the hydropower project (REP1) has the highest overall score for employment impacts with a Ki value of 0.6169. In terms of creating jobs, this project performs superior to others across a range of sub-criteria. In the context of China's RE industry, REP1 are noted for their ability to generate employment throughout both the construction and operating phases, making them a substantial contributor to employment. The wind power project (REP3) has achieved second highest importance with a value of 0.5558. A wind power project also shows a favorable effect on employment. For manufacture, installation, and maintenance, wind power plants often need a professional personnel, which helps the RE industry create jobs. The solar power project (REP2) considered to be third important project. Compared to hydropower and wind power projects, solar power projects may create fewer jobs but still need workers for production, installation, and maintenance. The biomass power project (REP4) has achieved the lowest value; it means this type of RE project provides least employment opportunities in the context of China. Table 7 displays the various RE projects final rankings.

6. Discussion

According to the findings, hydropower projects may have the biggest potential to affect employment in China. Our results show that hydropower has tremendous job creation potential in China's RE sector are supported by several credible sources [37,38]. The Chinese government has actively promoted hydropower as a clean energy and job source. It has pledged to promote the hydropower industry and create jobs through various measures. China's commitment to the Belt and Road Initiative has led to international hydropower cooperation [53], which may create more local and international jobs. These sources, along with the previous ones, provide a thorough picture of hydropower's multidimensional role in employment creation and economic development in China. Moreover, hydropower projects often hire nearby residents. These jobs, from construction workers to technicians, offer rural residents job prospects [54]. Our analysis supports prior findings and emphasizes China's sustained investment in RE sources like hydropower as it seeks to meet its energy needs sustainably [9]. This emphasizes the necessity for responsible hydropower project development and implementation to maximize economic benefits while minimizing social and environmental impacts. The displacement of local residents and the destruction of ecosystems are just two examples of the considerable environmental and social effects that hydropower projects may have [55]. Therefore, before deciding whether to execute hydropower projects, a thorough analysis of their costs and advantages is

Table 6
The overall ranking of employment impacts sub-criteria with respect to the decision goal.

Code	Sub-criteria	Weight	Rank
EIC12	Number of jobs created per project	0.0990	1
EIC11	Number of jobs created per MW of installed capacity	0.0834	2
EIC41	Level of skill required for different types of jobs	0.0795	3
EIC33	Sustainability of employment over the project lifetime	0.0743	4
EIC43	Opportunities for skills development and career advancement	0.0724	5
EIC13	Types of jobs created in direct employment	0.0693	6
EIC22	Number of jobs created in related industries	0.0666	7
EIC32	Local hiring policies and practices	0.0642	8
EIC42	Availability of skilled workers in the local labor market	0.0639	9
EIC51	Average wage levels for different types of jobs	0.0593	10
EIC21	Number of jobs created in the supply chain	0.0587	11
EIC31	Percentage of local workers employed	0.0553	12
EIC53	Average wage levels in supply chain jobs	0.0541	13
EIC52	Wage levels compared to other industries in the region	0.0424	14
EIC23	Types of jobs created in indirect employment	0.0466	15

Table 7
RE projects final rankings.

Alternatives	RE project	Qi	Pi	Ki	Ranking
REP1	Hydropower	0.6444	0.5919	**0.6169**	1
REP3	Wind power	0.5787	0.5351	**0.5558**	2
REP2	Solar power	0.5617	0.5111	**0.5352**	3
REP4	Biomass	0.5222	0.4660	**0.4928**	4

required. The findings imply that wind power projects can significantly affect employment in China, notably in terms of job creation and local economic gains. The outcomes, however, also emphasize how critical it is to guarantee that labor norms and job quality are preserved in wind generating projects. This is in line with earlier studies that raised questions regarding the use of low-wage and insecure jobs in the wind energy sector [33,56].

Our findings align with Italy's experience, where RE investments may generate jobs and boost economic growth. Our findings imply that hydropower and wind energy projects can greatly improve job creation and economic development, supporting the premise that RE investments can boost the economy directly and indirectly [18]. Our findings support Italy's conclusions that RE investments can boost employment. The U.S. context with RE employment development supports with our results on wind power plants in China. Wind energy has tremendous job potential, according to our and the U.S. study. A compensation premium for green occupations, especially for low-educated workers, aligns with our emphasis on labor norms and job quality in wind energy projects [19]. Both studies emphasize the potential for RE to help fossil fuel workers transition. Moreover, our analysis highlights the benefits of sustainable energy growth in South Korea, including increased energy security and employment creation in the power generation industry. We stress the potential of Chinese hydropower and wind energy projects to create jobs, boost economic growth, and reduce greenhouse gas emissions. The South Korean scenario matches our results on RE's environmental and energy security benefits [20]. To alleviate joblessness in Ghana, agro-processing and tourism are being prioritized alongside RE measures to produce cash and create jobs. Our findings on preserving labor standards and job quality in wind energy projects support the focus on overcoming skill gaps and other challenges to maximize RE project employment benefits in Ghana [21]. The study also aligns with studies exploring the job-creating potential of RE projects in African countries. Our findings support the scalability and job generation potential of RE projects, which become more cost-effective as adoption increases [22].

The implementation of RE projects can have a substantial impact on regional economic growth and poverty reduction. Such projects can create job opportunities for the construction, installation, and maintenance of RE systems, particularly in rural areas with high unemployment rates. The renewable energy sector employed 11.5 million people globally in 2019, with solar photovoltaic (PV) and wind power providing most jobs [57]. The development of RE projects can also generate revenue for local governments through taxes, land leases, and community benefits agreements. Wind and solar projects in the US earned $1.6 billion in municipal taxes and lease payments in 2018 [58]. The Chinese economy put forth efficient renewable energy promotion polices to reap out the socio-economic and environmental benefits of renewable energy. Moreover, RE projects can increase access to affordable energy, particularly in remote areas, by powering practical purposes like irrigation systems and agricultural machinery, thereby reducing poverty. Decentralized RE technologies, such as off-grid solar PV systems, can also provide cost-effective solutions for rural electrification [59]. Additionally, the growth of RE projects can spur investments in local infrastructure, such as transmission lines, roads, and bridges, contributing to the region's overall economic development [60].

As mentioned, hydro energy use depends on water supplies and geography. Several factors justify building hydro energy systems over dispersed solar, wind, and biomass alternatives, despite its geographical restrictions. Hydro energy's high energy density and capacity factor are crucial. Hydroelectric power generates continuous and significant energy in suitable places. It has one of the greatest renewable energy capacity factors, often above 90 %. Its dependability and high output make it a clean energy source. Solar and wind energy systems, while essential, are intermittent and weather-dependent, resulting in energy generation variability. Hydro energy is a good choice in areas with sufficient resources due to its reliability and consistency. Second, hydro energy has significant environmental impact. Hydroelectric power has a lower carbon footprint than fossil fuel power. Their greenhouse gas emissions are low, supporting sustainability and emission reduction goals. Hydro energy plants' long lifespan—often decades—also boosts their environmental credentials. While solar panels are sustainable, their creation requires energy, which might affect their environmental impact. Hydro energy is also economically viable in some places. Hydro project investments can be high, while operational and maintenance costs are usually minimal. Hydroelectric power-harnessing locations benefit most from this cost-efficiency. Hydro facility building and maintenance jobs can boost local economies and promote adjacent communities. Finally, the energy landscape can be diversified to maximize each energy source's benefits. Hydro energy is reliable and can provide base-load electricity, supplemented by intermittent but valuable solar, wind, and biomass sources. A diverse energy portfolio can reduce the intermittency of some renewables, providing a more stable energy source.

This study contributes to the area by using a robust methodology and quantifying RE project employment implications. It reinforces hydropower and wind energy technologies' importance and provides a deeper understanding of their employment potential, helping policymakers and stakeholders make educated RE project development and job creation decisions. Therefore, the fuzzy AHP and fuzzy WASPAS techniques are useful tools for assessing how RE projects in China would affect employment. To support China's transition to a low-carbon economy, policies and strategies that encourage the development of RE projects with favorable employment implications are required. Furthermore, policies that encourage domestic RE technology production and labor development can boost the employment effects of RE projects. The results of this study thus add to the expanding body of knowledge about how RE projects affect

employment.

7. Conclusion and recommendations

It is challenging to emphasize the urgent need for a transition to a low-carbon economy on a global scale, primarily because it is essential to addressing climate change. certainly RE is an important aspect of this shift, which China has highlighted as its highest priority by establishing ambitious deployment goals. In addition to the environmental benefits, it is crucial to realize that the expansion of RE projects has the potential to provide a significant number of employment opportunities. In this regard, the fuzzy AHP and fuzzy WASPAS approaches have been used in this study to thoroughly assess the employment effects of various RE projects in China. The findings are crucial since they demonstrate that hydropower and wind projects have the potential to significantly boost employment in China. On the other hand, solar and biomass energy development initiatives seem to have a less significant effect on job growth. These findings have significant implications for Chinese policy and practice, highlighting the necessity of careful planning in the distribution of financing for RE projects.

7.1. Recommendations

Prioritization of Hydropower and Wind Energy Technologies: The findings indicate that hydropower and wind energy projects in China have the highest potential for creating jobs. It is crucial for the government and stakeholders to give top priority for the development and adoption of these technologies. Significant financial expenditures, research and development initiatives, and effective execution strategies should all be prioritized. The importance of these RE technologies increases job opportunities, improves China's energy security, and makes a significant contribution to the global necessity of lowering carbon emissions.

Comprehensive Evaluation: When evaluating the viability of RE projects, policymakers and stakeholders should take a comprehensive approach. This strategy should address variables from the social and environmental spheres in addition to economic aspects. These projects cost and benefit should be carefully weighed in sustainability evaluations to make sure they are consistent with social responsibility and environmental responsibility.

Community Involvement: Local communities should actively involve for RE adoption. To understand the needs, concerns, and preferences of local communities, policymakers and stakeholders must work closely with them. Participation of the general public in public forums, interviews, and seminars can increase trust in the RE technologies. Local communities can also provide invaluable insights into the local environment and culture, which can have a significant impact on the planning and implementation of RE efforts.

Supportive Policies and Incentives: Policymakers should establish supportive policies and incentives to promote the development of RE projects that contribute to job creation and local economic growth. By putting supportive laws and incentives in place, the growth of the RE sector can have a significant positive impact on nearby communities.

This study makes a substantial theoretical contribution to the field by assessing the employment effects of RE technologies using cutting-edge decision-making approaches, particularly fuzzy AHP and fuzzy WASPAS. This bridges the gap between theoretical knowledge and practical implementation by offering policymakers and stakeholders a systematic and quantitative framework for making informed decisions. The research emphasizes the necessity of giving hydropower and wind energy technologies top priority within China's plan for RE.

7.2. Future research and limitations

Future studies in the area of employment and RE in China should take into account a number of attractive avenues. First of all, it is crucial to undertake long-term analyses of employment implications in order to comprehend the viability of job creation in the RE sector. Through a longitudinal analysis, it is possible to determine whether the RE sector offers steady, long-term employment prospects or if there are cyclical shifts in labor demand. Furthermore, it is crucial to broaden studies to cover the wider social and environmental effects of RE initiatives. A more comprehensive understanding of the consequences of RE production on society and the environment can be obtained. Comparative studies between various regions of China can also provide insightful information on the disparities in employment impacts by region and assist with tailoring policies to particular local settings. This study has significant limitations even though it offers insightful contributions. One drawback is the lack of timely and accurate data, particularly for jobs in the RE industry. The validity of the findings could be impacted by data gaps and other biases because the conclusion is tailored to China's particular context and policy climate, and their applicability outside of China may be constrained. The fuzzy AHP and fuzzy WASPAS techniques both have underlying methodological assumptions that could inject subjectivity into the analysis. Alternative ways might be investigated in further research, or the results might be validated using various methodologies.

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Data availability

Data included in article/supplementary material/referenced in article.

CRediT authorship contribution statement

Gao Liu: Writing – review & editing, Visualization, Validation, Formal analysis, Data curation. **Tianchang Chen:** Validation, Resources, Methodology, Investigation, Data curation. **Xin Sui:** Project administration, Funding acquisition, Formal analysis, Conceptualization. **Yasir Ahmed Solangi:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

It is certified that authors have complied with ethical requirements and that this manuscript is neither submitted anywhere nor under consideration for publication elsewhere.

The authors declare that there is no conflict of interest with anyone else.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e22710.

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