Environmental Impact Assessment Review 89 (2021) 106585

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

Integrating climate change factor into strategic environmental assessment in China

Yiting Yang [a], He Xu [a,b,*], Jiawei Wang [a], Ting Liu [a], Huanzhi Wang [a]

[a] *College of Environmental Science and Engineering, Nankai University, Tianjin 300350, PR China*
[b] *Institute of Ecological Civilization, Nankai University, Tianjin, 300350, PR China*

ARTICLE INFO

Keywords:
Strategic environmental assessment (SEA)
Climate change
Low-carbon development

ABSTRACT

In recent years, climate change has caused a significant impact on the human living environment, and the greenhouse effect caused by gases such as carbon dioxide cannot be ignored. From the viewpoint of environmental management, Strategic Environmental Assessment (SEA) has the functions of value judgment, prediction, and behavioral orientation on the possible impact of strategic planning. Integrating climate change factors into the SEA process can help planners and decision-makers better highlight the importance of climate change in policy and planning stages. Therefore, by combining the development of the SEA of China with relevant international experience, we explore the integration of climate change factors into the SEA framework and construct a technical procedure for such an assessment. A suggestive assessment indicator system for the SEA based on low-carbon targets was established for evaluating the impact of the implementation of strategic planning on low-carbon development goals. The objective is to mitigate the impact of climate change via the SEA and to ensure that the assessment plays an important role in tackling climate change and promoting sustainable development.

1. Introduction

From the promulgation of the Environmental Protection Law of the People's Republic of China in 1979 to the implementation of the Law of the People's Republic of China on Environmental Impact Assessment (EIA) in 2003, China's strategic environmental assessment (SEA) has transitioned from the concept to legislation stages. The State Planning Commission, the State Capital Construction Commission, and the State Economic Commission and the Leading Group for Environmental Protection under the State Council promulgated the Measures for Environmental Protection Administration of Capital Construction Projects in 1981 to strengthen the implementation of project EIA. However, with the continuous development of economy and society, the inherent limitations of such assessment of construction projects have become increasingly clear. Since SEA can overcome these limitations, the Chinese government has focused on the status of SEA. In 1993, the National Environmental Protection Bureau first proposed regional EIA. New developments shall carry out regional EIA before construction activities. The assessment of the environmental quality, bearing capacity and pollutant discharge of the development zone provide a scientific basis for the planning, industrial structure and layout and environmental function zoning. Then in 1998, the State Council approved the Regulations on Environmental Protection Administration of Construction Projects, which required an EIA for regional development—this was the first time in China that regional EIA was clearly stipulated in the law. This assessment was similar to SEA in content, basic procedure, and mode.

To ensure the implementation and status of SEA, the EIA Law of the People's Republic of China was enacted in 2002, which legally necessitated the SEA. This law stipulates that all regions and industries must perform EIA of projects, plans, and programs, and requires that the scope of EIA in China should not be limited to the construction project EIA, but should include the assessment in all relevant fields at the strategic level. Generally speaking, the special planning in China covers industry, agriculture, animal husbandry, forestry, energy, water conservancy, transportation, urban construction, tourism and natural resources exploitation. The special planning shall organize EIA work before an examination of the special planning draft report. Meanwhile, it is essential to submit an environmental impact statement to the authority that examines and approves the special planning. The EIA Law also imposes relevant requirements on the work scope, examination

* Corresponding author at: College of Environmental Science and Engineering, Nankai University, No. 38 Tongyan Road, Haihe Education Park, Jinnan District, Tianjin 300350, China.

E-mail address: seacenter@nankai.edu.cn (H. Xu).

https://doi.org/10.1016/j.eiar.2021.106585
Received 14 July 2020; Received in revised form 7 March 2021; Accepted 8 March 2021
Available online 19 March 2021
0195-9255/

methods, working hours, institutions, legal responsibilities of SEA, contents of the EIA report, and other aspects. To promote the implementation of the EIA Law, the State Environmental Protection Agency successively promulgated a series of technical guidelines and standards, including the Technical Guidelines for Planning Environmental Impact Assessment (Trial) (HJ/T130-2003) and the Measures for the Review of Environmental Impact Statements of Special Plans. The Technical Guidelines for Planning EIA focuses on factors that may lead to climate change, such as greenhouse gas (GHG) emissions and climate change disasters. Since then, China has embarked on capacity building for SEA.

In 2009, the State Council adopted regulations on EIA for planning to strengthen such assessments, make strategic planning more scientific, prevent and control environmental pollution and damage at the source or early stage, and promote a comprehensive, coordinated, and sustainable development of economy, society, and environment. The council clarified that the planning organ is the main body of responsibility for EIA and standardized the content, basis, specific form, and public participation of the assessment. According to these regulations, the overall impact and long-term impact should be analyzed, predicted, and evaluated in the planning environmental impact assessment. Climate change is closely related to these impacts. The core problem that needs to be solved is the manner of conducting a planning environmental impact assessment. At the end of 2009, the Chinese government formally set a low-carbon development target of reducing carbon dioxide emissions per unit of gross domestic product (GDP) by 40%–50% from 2005 levels by 2020 and required that the control of GHG changes be included in the medium- and long-term development strategies and plans of the government.

In the same year, pilot practices of SEA were adopted and gradually widely applied. SEA of five regions as a representative of large regional SEA was considered for the “one place, three areas and ten special projects” legal evaluation scope. It is the first regional SEA that spans multiple administrative regions and industries. Thereafter, in 2012 and 2013, China conducted SEA on key areas and industries of China Western Development—city clusters on the Middle and lower reaches of the Yangtze River and Central Plains Economic Belt. In 2016, in the implementation Plan of the 13th Five-Year Plan for EIA reform, the Ministry of Environmental Protection required the strengthening of the management of space, total volume and environmental access by means of the ecological protection red line, environmental quality bottom line, resource utilization line, and negative list of environmental access. Gradually, the top-level design of SEA was optimized. Recently, via practical application, there has been a gradual improvement in SEA’s technical method, which is expected to play a greater role in policy and decision-making in the future.

Because of the value judgment, prediction, and behavioral orientation functions on the possible impacts of strategic planning, SEA will play an irreplaceable role in mitigating the negative impacts of climate change and achieving China’s sustainable development goals of low-carbon emission. Meanwhile, as the SEA is an important tool of environmental management, the most basic social function is integrating the environmental standard or criteria such as climate change into the definition of strategic planning and decision-making. It can help planners and decision-makers to better coordinate between environmental protection and economic growth for ensuring that future economic development can meet the demands of the environmental quality standards. Therefore, it is undoubtedly a win-win choice to incorporate the climate change factor into the SEA tools for effectively promoting low-carbon emission and sustainable development in China.

Efforts have been made to integrate climate change into the SEA system quite early, and a consensus has been reached. (Table 1).

Further advancements have been made and tools developed with the progress in research. Since 2015, computer-based tools have been provided at the website of <Climate & Disaster Risk Screening Tools> popularized by the World Bank; this website provides information regarding the screening process, screening tools, and screening

Table 1
Achievements about SEA with climate change factor in the world.

Nation/Organization/ Activity	Year	Events/ Significance
The United Nations Framework Convention	1992	Climate change should be considered in policies and actions ; Impact assessments should be used to minimize the negative effects of climate change on the economy, public health and environmental quality.
European Union	2001	In the European Union directive (2001/42EC), member states need to fully consider the impact on climate factors in implementing SEAs.
The Environment Agency with Natural England, Countryside Council for Wales, UK Climate Impacts Programme.etc.	2004	<Strategic Environmental Assessment and climate change: Guidance for practitioners> was developed.
The Australian Government	2006 (updated in 2007&2011)	<Climate change impact and risk management—A guide for business and government> was published to integrate climate change impacts into strategic planning activities and risk management.
The Netherlands Commission for Environmental Assessment	2007	Recommendations on climate change in the environmental assessment were provided.
The United Nations Development Programme	2007	Adapting to Climate Variability and Change: A Guidance Manual for Development Planning
	2015	Strategic Environmental Assessment Approach to Adaption
The European Commission/ Report:<Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment>	2013	It integrated environmental issues into plans, programs, and projects to resist and adapt to climate change and tackle the loss of biodiversity and degradation of ecosystems. The report provides guidelines and recommendations to integrate climate change and biodiversity in SEA. It takes full advantage of the contribution of SEA in an early stage and thus reduces vulnerability and increases the resilience of natural and human systems.
Ireland	2015	The report <Integrating climate change into SEA: A Guidance Note> was published.
The Institute of Environmental Management and Assessment (IEMA)	2015	The IEMA Environmental Impact Assessment Guide to Climate Change Resilience and Adaption was published.
Canada	2019	<Strategic Assessment of Climate Change (draft) > provides guidance on the manner wherein federal impact assessments will consider the GHG emissions of a project and its resilience to climate change impacts.
The Scottish Government	2020	<Proposals for a New Climate Change Bill> which includes the integration of environmental considerations into the climate change bill.

resources for users.

These legal works and related reports have been accompanied by related academic research. Shillington et al. first proposed to integrate climate change factor into the environmental assessment process. In the study of SEA for sewage treatment in 2003, Poulsen and Hansen innovatively proposed to consider the impact of global warming as a part of the evaluation of alternative schemes(Poulsen and Hansen, 2003). In 2008, Wilson and Piper advised EIA and SEA as tools and means to cope with climate change(Wilson and Piper, 2008). Noble and Christmas initially proposed a planning EIA methodology framework incorporating climate factors through GHG mitigation studies in the agricultural sector(Noble and Christmas, 2008). Schwarz et al. described an evaluation method of the impacts of local and regional planning policies based on a case study in Leipzig in Germany(Schwarz et al., 2011). In 2011, Posas studied the standards and practices action for considering climate change factor in environmental analysis and SEA(Posas, 2011). Wende et al. explained the need for methodological guidance on the strength of land use plans to consider global climate change factor into regional levels by the example of German and England regions(Wende et al., 2012). A hypothetical model was developed during the analysis of 151 Danish SEAs by Larsen et al. to show how SEA practice handles climate change uncertainties(Larsen et al., 2013). More recently, Weiskopf et al. reviewed the climate change effects on biodiversity, natural resource management, and ecosystems service in the United States (Weiskopf et al., 2020). With the advances made in relevant academic research, most developed countries and international organizations successively introduced various regulations, guidelines, policies, and other measures that explicitly require the integration of climate change factors into the SEA process and its institutionalization.

Currently, China's economy has shifted from a stage of rapid growth to a stage of high-quality development and is at a crucial stage of transforming the growth model, optimizing the economic structure, and transforming the driving force for growth. China's sustainable development cannot be achieved without strategic planning. However, SEA thriving with regional and industry development in China still lacks some crucial factors such as climate change that may influence our living environment. For the purpose of exploring the means for integrating climate change factor into SEA in China, a SEA technology procedure based on low-carbon development goals is described in chapter 2. An indicator system to be used when integrating climate change factors into each stage of the SEA is proposed. Chapter 3 provides the conclusions and several policy-related suggestions.

2. Technical structure of SEA by integrating climate change factor in China

2.1. Assessment view and goals

Reducing the share and amount of GHG emissions is important for mitigating the impact of human activities on climate change. GHGs, such as carbon dioxide, are the main cause of climate warming. Low-carbon development refers to minimizing the emission of carbon dioxide and other GHGs during economic development. In this context, a new development model is on account of the basic requirement of coping with the impact of using carbon-based energy on climate warming. Such a model will be a positive development, enabling a transition from the era of high-carbon energy to the era of low-carbon energy. However, the vast majority of China's strategic planning does not take into account the factors of low-carbon development and lacks effective evaluation criteria and tools. Therefore, effective approaches and tools to integrate low-carbon development targets into the policy-making and decision-making process and to transform low-carbon development from policy into a guideline for social and economic activities are lacking.

SEA is a multi-objective evaluation tool to optimize decision-making and promote sustainable development(Fidelis and Rodrigues, 2019). Low-carbon development is an effective and specific way to mitigate the impact of climate change. Strategic evaluation based on low-carbon development goals should focus on the analysis of the coordination and effective combination of low-carbon development goals and ecological environmental protection and energy conservation goals, development goals of circular economy, emission reduction goals, and coordination between the relationship and the rational integration into the existing development planning system. The basic task involves the strategic planning and preparation stage. It includes proposing low-carbon measures and suggestions for the industry, energy, transportation, construction, and cost systems through the low-carbon development goals of accessibility analysis, prediction and evaluation of the proposed planning carbon emission effect.

2.2. Technical procedure

In China, SEA usually focus on regional and industrial plans; for a comprehensive low-carbon development evaluation, some factors related to low-carbon development should be integrated into assessment working process. The low-carbon factor is considered in the processes of screening, scoping, establishment of assessment goal and indicator system, predictive analysis, and decision-making. Low-carbon goals are incorporated into the SEA technical procedure. (Fig. 1)

2.3. Assessment content

2.3.1. Screening

To improve the efficiency of SEA, screening the type of the suggested strategic plan to be evaluated is needful so as to identify whether the plan needs low-carbon development evaluation. For this purpose, verification tables and expert consultations are employed to preliminarily judge the interaction between strategic planning and carbon emissions in China. Based on relevant principles and regulations on SEA of strategic planning, preliminary identification of the national economy and social development plan, the following conclusion is drawn: The national comprehensive planning of economic and social development, industrial energy guidance and special planning, and city construction special planning deeply influence the carbon emission and degree of the low-carbon development. In practice, the decision of whether the SEA should include a comprehensive carbon emission analysis and low-carbon evaluation depends not only on the type of the planning but also on multiple factors such as the development scale of the planning design and the scope of economic activities.

Because low-carbon development depends not only on the type and nature of the planning but also on the comprehensive consideration of the development scale and the scope of economic activities, the judgment of low-carbon evaluation level can be explored in specific work. After the preliminary determination of the level, a comprehensive understanding of the evaluation objects should be obtained: the SEA should briefly explain and analyze the compilation background, planning goals, planning contents, implementation plans and relations with other strategic planning activities. The SEA based on the low-carbon development goal identifies the degrees of interaction and integration of the proposed strategic plan to the low-carbon concept and low-carbon development goal through planning analysis, so as to determine the work level, work task, and assessment goals. This progress mainly includes a coordination analysis of the plan related to low-carbon development, analysis of the integration degree between planning content and low-carbon development, and the identification of SEA tasks.

2.3.2. Scoping

2.3.2.1. Carbon emission status survey. Carbon emission status investigates carbon source and sinks, energy emissions, social economy and other aspects of the region or industry related to carbon emission.

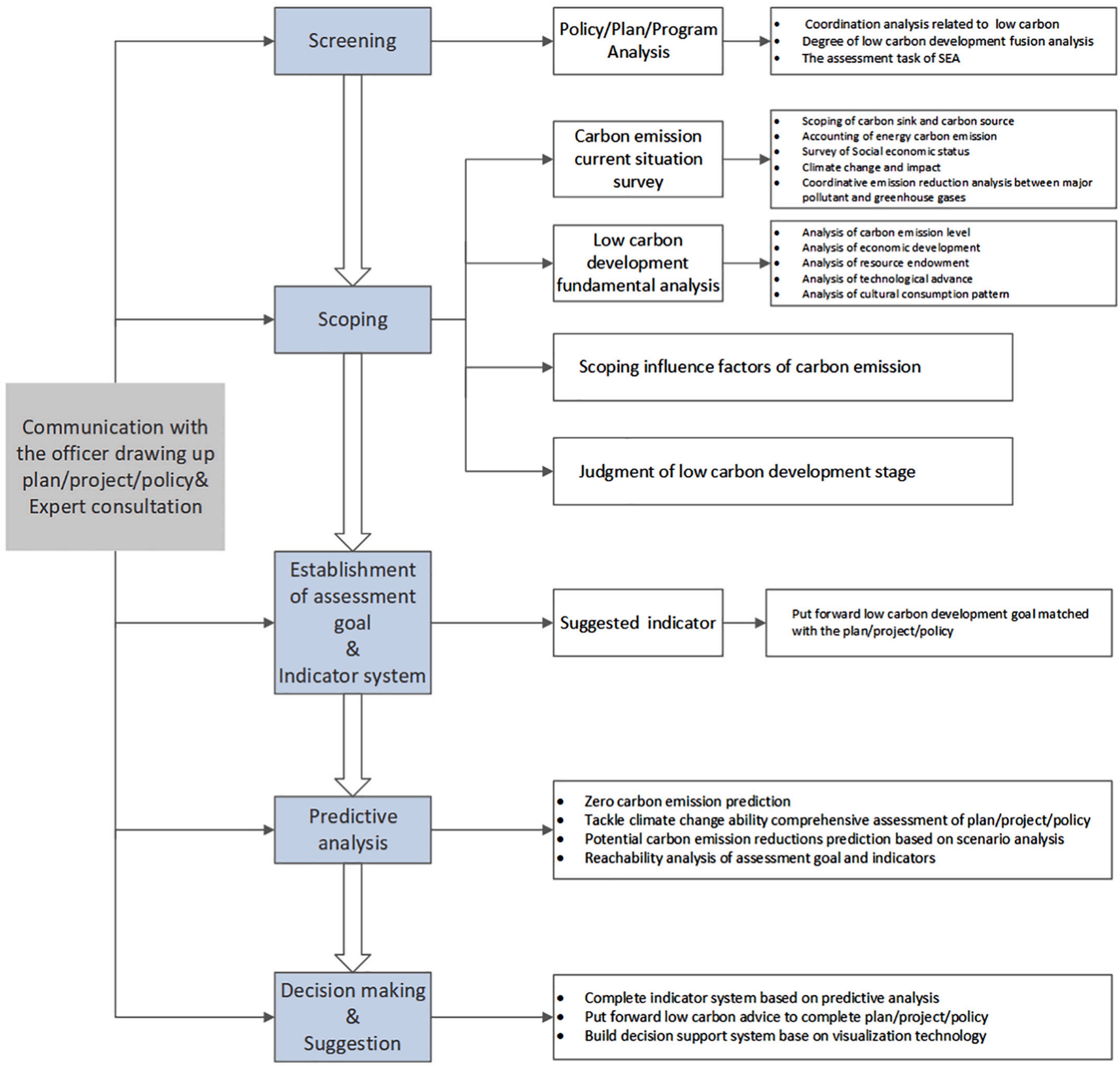

Fig. 1. Technical procedure of Strategic Environmental Assessment (SEA) based on low-carbon development targets in China.

The investigation of the current SEA situation has the function of knowing the status of pollution sources and environmental quality within the evaluation region. It can also make a contribution to provide the basis for identifying evaluation factors and selecting target indicators. The status survey of SEA investigates the major carbon sources and sinks in the region or industry, including five major types—energy activities, industrial production process, agricultural activities, land use change, and urban waste treatment—to clarify the current state of GHG emissions. This status survey should also be combined with and communicated in the technical process of SEA to provide basic data for the SEA prediction and evaluation model and thus should include energy and carbon emission accounting, social economy, and other aspects. Carbon emission accounting can help grasp the status of regional or industrial carbon emission and calculate the total carbon emission and emission distribution in the region or industry. The social and economic investigation related to carbon emission includes the status of both economic industrial and social development, especially focusing on the analysis of the development of energy-intensive and technology-intensive industries. Furthermore, as low-carbon development is a reasonable and necessary response to global climate change, the SEA based on low-carbon development goals should consider the regional climate change and corresponding adaptation measures.

2.3.2.2. Analysis of low-carbon development. Effective coordination between economic growth and carbon emission reduction is the key to a transformation of regional low-carbon development. Such low-carbon development of different regions/industries should fully exploit their own potential advantages and choose diverse low-carbon paths based on resource endowment and industrial development characteristics. Carbon emissions should be reduced to the maximum extent possible on the premise of ensuring economic development for the purpose of coping with global climate change. For the SEA to scientifically and effectively evaluate the low-carbon development content of strategic planning and realize low-carbon development goals, it is vital to comprehensively evaluate the status and characteristics of the region/industry from four perspectives—economic development stage, resource endowment, technological progress and consumption pattern—to identify the basis, opportunities, and potential of low-carbon development. The comparison of regional/industrial carbon emission level between the domestic and international levels can help determine the low-carbon level of economic development.

2.3.2.3. Identification of carbon emission influence factors. Owing to large differences in economic development, resource endowment, technological level, and living customs in different regions, the main factors influencing the carbon emissions as well as the contributions of different factors to the growth of carbon emissions differ greatly. Therefore, the SEA based on low-carbon development should comprehend the main contradiction of regional/industrial low-carbon development and identify the carbon emission influencing factors. Using the carbon emission factor decomposition method and analysis model, we can decompose the historical carbon emission data of the region/industry from different viewpoints. Kaya decomposition and LMDI decomposition were used to study regional and industrial carbon emissions, and quantitatively analyze the contribution rates of economic development, energy structure, energy structure, energy efficiency and population factors to the emission increase over the years (Štreimikienė and Balezentis, 2016) (Zhao et al., 2010). The IPAT model was used to study consumption-based carbon emissions, and the impact of population structure evolution on carbon emissions was quantitatively analyzed(Brizga et al., 2013). This foundation of the SEA indicator system is an important part of the process of strategic planning and decision-making in the SEA.

2.3.2.4. Determination of the low-carbon development stage. Because of differences in economic development levels, natural resource endowment, and technology levels, low-carbon development in different regions/industries is at varying stages with differing development characteristics. For ensuring balanced development among regions and reasonable development space among industries, it is essential to develop a low-carbon development mode that not only adapts to its own characteristics but also guarantees the national carbon emission target on account of the characteristics of the low-carbon development stage of the region/industry when formulating the low-carbon development goals and carbon emission targets of the region/industry.

Generally, four indicators—carbon emission intensity, resource and negative index, the proportion of energy-intensive industries, and per capita GDP—are used to determine the factors that characterize the low-carbon development stage in different regions in China. Based on the actual situation of the region to be evaluated and the availability of data, the quantitative indicators best reflecting the carbon emission level, natural conditions, industrial structure, and technological level as well as the level of economic development of the region shall be selected appropriately. Then, a regional development radar map composed of the index values and the national average in that year is generated. A radar map (also known as a spider map) is a graph that presents multidimensional data in two dimensions. It is composed of a set of coordinates and several concentric circles chart. It can show the analysis of multiple indicators in the same coordinate system, and often be used for a comprehensive evaluation of various industries. Using the radar map, the low-carbon development types of the region/industry—i.e., developed low-carbon development (Type 1), balanced low-carbon development (Type 2), resource-based high-carbon development (Type 3) and developing high-carbon development (Type 4)—are determined on the basis of consultation with experts and relevant departments.

For “Type 1” regions, the SEA should be centered on further optimizing the structure of energy and industry, increasing the proportion of knowledge-intensive industries, and prioritizing the setting of indicators such as the structure of energy and industry, in particular, nuclear energy structure, and the rationality of development goals of strategic planning. For “Type 2” regions, the SEA should thoroughly analyze the structure of energy utilization and mechanism of regional economic development based on the approachability of low-carbon development goals. For “Type 3” regions, the SEA should consider the economic development measurement indicators to promote the rapid economic development of the region as well as the reduction performance of regional carbon intensity quantitatively by means of process indicators. With regard to “Type 4” stage seen in most regions of China, the SEA should comprehensively analyze the basic conditions and opportunities for regional low-carbon development and develop evaluation indicators for the development stage, industrial structure, energy utilization, technological level, and system construction.

The action of low-carbon industry development level evaluation can guarantee the development space of the industry. By comparing international and domestic advanced energy consumption standards and the advanced technology and clear technology penetration rates of the same industry, the current development stage of the proposed industry planning can be identified to better optimize and upgrade the industrial structure and replacement. Further, such evaluation will contribute to achieving the low carbonization of industrial development.

2.3.3. Assessment indicator system

Integrating low-carbon development targets into SEA allow include the abstract concepts of low-carbon development and macro strategy into concrete projects. It is a feasible and effective measure to actualize low-carbon development strategy. The core task—the construction of a feasible indicator system, planning analysis, and summarization of the results of the current situation investigation and research—can lay the foundation for the prediction analysis and comprehensive evaluation and provide an important basis for planning improvement and practical guidance.

Although in China, some progress has been achieved in the research and practical application of the SEA, a theoretical basis is lacking, and an SEA indicator system for environmentally sustainable development is necessary. In recent years, with the development of social emergency responses and the improvement of environmental protection awareness, strategic planning has gradually incorporated environmental protection content. In the planning text, environmental protection is more or less integrated into the consideration, and environmental indicators are clearly added in the indicator setting. The SEA indicators based on the low-carbon development goals should focus on the judgment of the strategic planning itself and should comprehensively evaluate the degree of integration of the proposed planning with the low-carbon concept and the degree of coordination of the carbon emission goals. For fully reflecting the functional orientation of SEA, an indicator system based on low-carbon development targets is constructed as a useful tool below.

The recommended indicators of low-carbon assessment should be built around the regional/industrial carbon emission goals(Helbron et al., 2011). Since the indicator system is intended for different types of users—evaluators, decision-makers, the public, etc.—the formulation of the indicators should fully reflect different characteristics. During the development of the indicators, in order to fully describe the overall representation of the complex system of low-carbon development, the carbon emission level indicators should correspond to other relevant indicators, reflect the response to relevant development policies and priority targets, and reflect the efforts and performance of the region/industry in low-carbon development.

As energy consumption, economic development, resource endowment, and social sturcture have a close relationship with low-carbon development and carbon emissions, the assessment index system in SEA should not only focus on the level and status of carbon emissions but also the factors that cause adverse and powerful changes in the carbon emission indicators. This complete assessment index system should be comprehensive and scientific enough to assess the condition of low-carbon development. So in this study, the pressure-state-response (PSR) model, an indicator system widely used in the field of environmental protection and sustainable development in the world, was adopted to build a model. The PSR model was initially proposed by Canadian statisticians David J. Rapport and Anthony Marcus Friend in 1979 and later developed by the Organization for Economic Cooperation and Development (OECD) and the United Nations Environment Programme (UNEP) in the 1980s and 1990s for the study of environmental issues(Wang et al., 2019). It is a commonly used evaluation model in the sub-discipline of ecosystem health evaluation in environmental quality evaluation. This model highlights the causal relationship between environmental pressure and environmental degradation and ensures the coordination and integrity of the indicator system. The indicators of pressure, state, and response meet the requirements of SEA index system in reflecting the state, influence, and development trend of environmentally sustainable development. Stress indicators reflect the impact of strategic implementation on resources, environment, and social systems. State indicators are used to reflect the status of resources, environment, and society, including resource status indicators, environmental quality indicators, and social status indicators. Meanwhile, the response indicators reflect the efforts of human society to reduce environmental pollution and resource depletion. (Table 2)

The suggested indicator system is integral and mutually connected: the pressure indicator is the driving force measure of the status indicator, and the response indicator is the measure of the action taken to achieve the status indicator and the expected effect. Therefore, pressure indicators, process indicators and response indicators should be subject to state indicators, and the key to determining index values is to first determine the target value of regional/industry carbon emissions. However, carbon emission standard value is different from the pollutant emission standard. There is neither an emission threshold nor regional environmental quality standard. It only belongs to the scope of total quantity control, and it is a global total quantity control. The only national reference standard for China's carbon emission is the carbon intensity emission target of 40% and 45% proposed by the government. Besides, the national administrative department set the regional or industry responsibility-sharing. Therefore, the determination of energy consumption index per unit of GDP, regional and industrial carbon emission index values will more often be based on the actual situation of their own development and mainly depend on the national administrative distribution system. In addition, different development regions have different requirements and priorities for low-carbon development. So considering the carbon emission indicators, the national, industrial, or local standards should be adopted to meet the regional/industrial decomposition requirements of carbon emission targets. Depending on the low-carbon development stage of the region/industry, the appropriate target standard value was determined based on the socioeconomic development planning goals for the evaluation area. Then, through expert consultation and communication with the relevant departments and with the aid of scenario analysis and other prediction methods, the accessibility of the target value was comprehensively analyzed using the two-way communication mode of the PSR model. Finally, the target value was determined.

Table 2
Suggestive assessment indicator system for the SEA based on low-carbon targets.

Target	Criterion	Assessment content	Assessment indicator
Low-carbon development target assessment	Pressure indicator A	Economic development A1	GDP/GDP per capita
			Annual per capita income
			Added value of key industries
		Energy consumption A2	Fossil energy consumption/per capita fossil energy consumption
		Resource endowment A3	Renewable energy sources yield
			Resource endowment index
			Area fossil energy yield
		Population situation A4	Population scale
			Population structure
			Urbanization level
	State indicator B	Region carbon emission level B1	Per capita carbon emission
			Carbon emission intensity per ten thousand Yuan
			Carbon productivity
		Industry carbon emission level B2	Carbon emission intensity per industry added value
			Per product carbon product
			Per capita carbon emission consumption
	Process indicator C	Carbon emission reduction performance C1	Carbon emission elasticity
	Response indicator D	Industry response D1	The third industry proportion
			Proportion of high energy consumption on industry
		Energy response D2	Energy utilization efficiency
			Use proportion of renewable energy resource
		Traffic response D3	Proportion of rail transit trip
			Proportion of green traffic
		Policy response D4	Building energy conservation reform proportion

2.3.4. *Predictive analysis based on target accessibility*

The target accessibility means the realization degree of the low-carbon development target. Predictive analysis based on target accessibility indicates the coordination of economic development and national carbon emission targets. The SEA predictive analysis is based on the requirements of evaluation goals and indicators to analyze the character, extent, and scope of the impact of strategic planning implementation on the environmental quality and ecosystem. This analysis is based on low-carbon development goals and does not involve the analysis and prediction of the carbon emission target of a region/industry and the accessibility of the development index value proposed by the SEA. Instead, it should include the assessment index system in the construction process. In general, the carbon emission level of the region/industry is characterized by indicators such as total carbon emission, carbon emission intensity per unit of the GDP, carbon emission per capita and per unit product. Since most of China is in the course of incremental control of carbon emission characteristics and low-carbon development goals based on the carbon intensity characteristics, the most important aspect of the SEA predictive analysis is the determination of carbon intensity via in-depth analysis and forecasting of the future region/industry, including accessibility analysis and intensity target contribution analysis of the target of the national strength. Thus, the predictive analysis can promote the coordination of economic development and the carbon target of the country.

Current carbon emission prediction methods mainly involve quantitative model calculation and comprehensive scenario analysis. Carbon emission is a relatively complex system, which is greatly influenced by various factors such as the industrial scale, industrial structure, the intensity and structure of energy consumption, technological level, living standards and policy system. The calculation method of the quantitative model is based on a simplification of the complex system. The method is based on the assumption that the future system will continue following the development law of history and trend extrapolation analysis. The prediction is based on historical statistical data. Owing to the uncertainty in future development and possible structural changes in the system, several comprehensive models of carbon emissions now incorporate scenario analysis and forecast carbon emissions under different scenarios for different model parameters(Wu et al., 2018). The SEA evaluation objects are generally medium- and long-term strategic plans. In China, medium - and long-term planning conducted by the government plays an important role in the development of the whole country. Therefore, the pilot stage of SEA should focus on national medium - and long-term planning.The traditional thought process based mainly on trend extrapolation and time series prediction should be changed, and the focus should be on the root cause of various uncertain factors via scenario analysis; the system development rule should be determined to predict different future carbon emission scenarios better and to provide a more scientific judgment basis for decision makers.

The most basic social function of SEA is to integrate environmental quality standards into the formulation and decision-making process of strategic planning. In the future, the SEA will become an important yardstick to measure the environmental friendliness of regional and environmental planning. Meanwhile, it also has the function of integrating the factors of sustainable development into the formulation and decision-making process of strategic planning and undertakes the new function of optimizing decisionmaking from social, economic, environmental and other aspects. As a result, based on the social function of the SEA and the characteristics of carbon emissions, a qualitative–quantitative analysis model should be adopted for carbon emissions. The SEA qualitatively describes the complex system development of carbon emissions; further, it quantitatively predicts carbon emissions through the quantification of scenario parameters. The scenario analysis based on low-carbon development predictions mainly identifies the factors with the greatest impact on the carbon emissions of the region/industry as the driving force. These factors include both external conditions such as macroeconomic conditions and social and policy development as well as internal factors such as the efficiency of energy-consuming equipment and process route at the micro level. Through the analysis of qualitative–quantitative description of the driving force, the uncertainty was analyzed, and definite quantitative indices were considered as the constraint conditions. Under the constraint conditions, the quantitative description was obtained. Through expert consultation, analogy analysis, and other methods, the settings of uncertain parameters were quantified. Then, using the carbon emissions accounting model, the accessibility of low-carbon development goals in different situations was calculated.

2.3.5. Decision and proposal

In the decision-making and proposal stage, the quantitative results of the accessibility improvement analysis should be summarized according to the evaluation indicators. The target indicator system proposed by the SEA should be transformed into specific socioeconomic behaviors; that is, the indicators in the indicator system should be implemented to promote the low-carbon transformation of the development mode of the region/industry.

First, the transformation of carbon-based energy into non-carbon energy should be accelerated to change the carbon emission characteristics at the source. Meanwhile, clean and renewable energy such as hydropower, wind, solar, tidal, and nuclear energy sources should be utilized well. Further, the proportion of new energy in the energy structure should be gradually increased. Second, the focus should be placed on low carbonization for economic development as well as social development. The implementation of the continuous promotion of circular economy and clean production can minimize the use of high-carbon energy and raw material input and indirectly reduces carbon dioxide emissions. Optimizing the industrial structure is an important measure for achieving low-carbon development. The economic structure and development speed of high-carbon industries determines the emission intensity of GHGs to a certain extent. Hence, adopting green travel and consumption methods, advocating the consumption of low-carbon products, and promoting the concept of energy conservation are important measures to realize a low-carbon society. Finally, there should be focus on the research and promotion of no-carbon new energy. The urgent task for the long-term strategic goal of building a low-carbon social system is to capture, store, and even recycle carbon dioxide from the end.

3. Conclusions and suggestions

This paper reports methods for integrating climate change into the SEA framework in China by considering low-carbon development goals. Carbon emission reduction must be considered at the screening, scoping, indicator-system building, predictive analysis, decision-making, and proposal stages. Through perfect strategic planning decisions that promote low-carbon industries and low-carbon energy and involve a construction of a carbon sink system with positive development can ensure the premise of rapid and good social economy and change the pattern of China's social and economic development. At the same time, it is important to fully consider the impact of climate change and low-carbon development goals in the SEA not only for improving the SEA in terms of scientific rationality and proposals, but also for ensuring that the SEA plays a bigger role in tackling climate change and has greater applicability in the national macro decision-making. In the long run and from the perspective of sustainable development, incorporating the SEA combined with the climate change factor into macro planning on the decision-making level is advisable.

3.1. Incorporating SEA concerns on low-carbon factors into relevant laws

In China, national strategic planning dominates the social development of the whole country. Strategic planning stipulates the overall direction and objectives of national development in the future period and plays a guiding role in national development. Against this background, the concept of climate change and low-carbon development target must be integrated into the development strategic planning of governments at all levels. If the SEA involved in the comprehensive decision-making and strategy formulation has legal effectiveness and can legally be enforced and obeyed in China, it will provide the legal guarantee for the promotion of low-carbon development. As an effective decision-making assistance tool and information communication platform, the SEA provides the opportunity and support for the implementing of low-carbon concept. And thus, the low-carbon development vision of the central government can be put into specific plans and practical actions of local governments(do Nascimento Nadruz et al., 2018). In the future, China can gradually consider incorporating the SEA with the goal of low-carbon development into the national legal system, standardize the technical methods and guidelines for evaluation, and establish and improve targeted management procedures and review mechanisms. Through improved governance, climate change concepts can be emphasized within the national planning and decision frameworks. This can not only ensure the implementation of a further improved SEA, but also greatly enhance the performance of low-carbon development in strategic planning.

3.2. Low-carbon factors to assist urban planning and construction

At the stage of urban planning and design, environmental issues should be organically combined with the planning objectives by adhering to low-carbon concepts. With the assistance of experienced communication specialists, the social development value and environment loss should be evaluated. Pilot projects on low-carbon SEA should be conducted, and cities should be built with reasonable structures and coordinated sustainable development, starting from implementing the "low-carbon" concept in various construction processes as well as urban planning processes such as functional positioning and development goals, urban scale, spatial layout, industrial development, transportation development, resource utilization, and infrastructure construction. Decision-makers should be informed of the relevance and implications of climate change to the policies, plans, and programs at the preliminary stage. While an urban economic development index is developed, a low-carbon index such as Carbon emission intensity per industry added value should be developed. Meanwhile, performance of carbon intensity reduction should be quantitatively studied to realize the sustainable development of cities.

3.3. Greater applications of SEA results

The SEA based on low-carbon development targets focuses on the comprehensive analysis and recognition of the current situation of the complex ecosystem. It involves a comprehensive investigation and evaluation from the perspectives of the stage of economic development, resource endowment, technological progress and consumption patterns. It helps further understand the environmental function of the regional ecosystem and clarify the main impact and existing problems. The emphasis on SEA evaluation results should not be limited only to the index value and evaluation conclusion; instead, it should include the investigation and analysis of the current low-carbon development of the area, and the analysis of the basis of regional low-carbon development. This will help identify methods and directions to optimize regional/industrial development.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research was financially supported by the Chinese National Funding of Social Sciences (grant number 18VZL014).

References

Brizga, J., Feng, K., Hubacek, K., 2013. Drivers of CO2 emissions in the former Soviet Union: A country level IPAT analysis from 1990 to 2010. Energy 59, 743–753. https://doi.org/10.1016/j.energy.2013.07.045.

do Nascimento Nadruz, V., Lucia Casteli Figueiredo Gallardo, A., Montaño, M., Ramos, H.R., Ruiz, M.S., 2018. Identifying the missing link between climate change policies and sectoral/regional planning supported by Strategic Environmental Assessment in emergent economies: Lessons from Brazil. Renew. Sust. Energ. Rev. 88, 46–53. https://doi.org/10.1016/j.rser.2018.02.006.

Fidelis, T., Rodrigues, C., 2019. The integration of land use and climate change risks in the programmes of measures of River Basin plans – assessing the influence of the water framework directive in Portugal. Environ. Sci. Pol. 100, 158–171. https://doi.org/10.1016/j.envsci.2019.06.013.

Helbron, H., Schmidt, M., Glasson, J., Downes, N., 2011. Indicators for strategic environmental assessment in regional land use planning to assess conflicts with adaptation to global climate change. Ecol. Indic. 11, 90–95. https://doi.org/10.1016/j.ecolind.2009.06.016.

Larsen, S.V., Kørnøv, L., Driscoll, P., 2013. Avoiding climate change uncertainties in strategic environmental assessment. Environ. Impact Assess. Rev. 43, 144–150. https://doi.org/10.1016/j.eiar.2013.07.003.

Noble, B.F., Christmas, L.M., 2008. Strategic Environmental Assessment of Greenhouse Gas Mitigation Options in the Canadian Agricultural Sector, 41, pp. 64–78.

Posas, P.J., 2011. Exploring climate change criteria for strategic environmental assessments. Prog. Plan. 75, 109–154. https://doi.org/10.1016/j.progress.2011.05.001.

Poulsen, T.G., Hansen, J.A., 2003. Strategic environmental assessment of alternative sewage sludge management scenarios. Waste Manag. Res. 21, 19–28. https://doi.org/10.1177/0734242x0302100103.

Schwarz, N., Bauer, A., Haase, D., 2011. Assessing climate impacts of planning policies—an estimation for the urban region of Leipzig (Germany). Environ. Impact Assess. Rev. 31, 97–111. https://doi.org/10.1016/j.eiar.2010.02.002.

Štreimikienė, D., Balezentis, T., 2016. Kaya identity for analysis of the main drivers of GHG emissions and feasibility to implement EU "20–20–20" targets in the Baltic States. Renew. Sust. Energ. Rev. 58, 1108–1113. https://doi.org/10.1016/j.rser.2015.12.311.

Wang, Q., Li, S., Li, R., 2019. Evaluating water resource sustainability in Beijing, China: combining PSR model and matter-element extension method. J. Clean. Prod. 206, 171–179. https://doi.org/10.1016/j.jclepro.2018.09.057.

Weiskopf, S.R., Rubenstein, M.A., Crozier, L.G., Gaichas, S., Griffis, R., Halofsky, J.E., Hyde, K.J.W., Morelli, T.L., Morisette, J.T., Muñoz, R.C., Pershing, A.J., Peterson, D. L., Poudel, R., Staudinger, M.D., Sutton-Grier, A.E., Thompson, L., Vose, J., Weltzin, J.F., Whyte, K.P., 2020. Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. Sci. Total Environ. 137782 https://doi.org/10.1016/j.scitotenv.2020.137782.

Wende, W., Bond, A., Bobylev, N., Stratmann, L., 2012. Climate change mitigation and adaptation in strategic environmental assessment. Environ. Impact Assess. Rev. 32, 88–93. https://doi.org/10.1016/j.eiar.2011.04.003.

Wilson, E., Piper, J., 2008. Spatial planning for biodiversity in Europe's changing climate. Eur. Environ. 18, 135–151. https://doi.org/10.1002/eet.476.

Wu, C.B., Huang, G.H., Xin, B.G., Chen, J.K., 2018. Scenario analysis of carbon emissions' anti-driving effect on Qingdao's energy structure adjustment with an optimization model, part I: carbon emissions peak value prediction. J. Clean. Prod. 172, 466–474. https://doi.org/10.1016/j.jclepro.2017.10.216.

Zhao, M., Tan, L., Zhang, W., Ji, M., Liu, Y., Yu, L., 2010. Decomposing the influencing factors of industrial carbon emissions in Shanghai using the LMDI method. Energy 35, 2505–2510. https://doi.org/10.1016/j.energy.2010.02.049.