Urban-Act
Integrated Urban Climate Action
for Low-Carbon & Resilient Cities

Climate Change Strategies in Spatial Planning: A Review of EU Experience

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Beijing, December 2024

Table of Contents

Tables

Figures

1. Introduction

1.1 The Correlation between Space and Addressing Climate Change

Addressing climate change includes two aspects: "mitigation" and "adaptation". Among them, climate change mitigation is achieved by adopting different planning methods to reduce greenhouse gas emissions or increase carbon sinks, thereby slowing down the rate of climate change; climate change adaptation is achieved by strengthening risk identification and management of natural ecosystems and economic and social systems, taking effective adjustment and adaptation actions, and reducing the adverse effects and risks of climate change.

From the relationship between space and greenhouse gas emissions, a reasonable urban spatial form can effectively reduce energy use and greenhouse gas emissions, thereby mitigating climate change [1]. The mitigation strategies for the spatial planning system mainly rely on planning methods or construction control to construct or improve the spatial form and resource elements of the city, to reduce greenhouse gas emissions and increase carbon sinks. There are various measurements to associate spatial form with greenhouse gas emissions, including urban density control, land use planning, energy-saving and low-carbon transportation system construction, green space system construction, energy-saving and green building planning and design, high pollution industry transformation, green energy structure adjustment, and other models [2,3]. Exploring the implementation of mitigation strategies under the spatial planning system is considered as a key countermeasure for shaping urban spatial form to address climate change.

From the relationship between space and climate change risks, a reasonable urban spatial form can not only reduce the frequency and intensity of extreme climate events, but also enhance the resilience of cities to cope with climate change, thereby adapting to climate change [1]. The adaptation strategy under the spatial planning system mainly relies on the construction of disaster prevention and mitigation infrastructure, to reduce the destructive power of extreme climate disasters and the frequency of disasters, thereby enhancing the ability to adapt to climate change. The spatial form can be linked to climate change risks through urban density control, building layout and ventilation corridor construction, transportation system adjustment, rainwater management, infrastructure lifeline safety construction, water management, etc. [3]. Further, the implementation of adaptation strategies under the spatial planning system can reduce the vulnerability of cities to climate risks and strengthen urban resilience, improving the overall ability of society to respond to climate change.

1.2 The Necessity of Integrating Climate Change Response into Spatial Planning

From the perspective of policy formulation, "space" is the carrier for social and economic departments to formulate policy goals and specific actions. Goals and actions only have practical significance when placed in "space", so goals and actions often have certain spatial directionality. However, when formulating policies based on departmental interests in various sectors such as industry, energy, environmental protection, construction, and transportation, it often leads to overlapping and interlocking of multiple goals or actions in a single space, and even conflicts in goals or actions, if coordination and consistency are not achieved on the "space" platform. To effectively avoid such situations, "spatial planning" has its prominent advantages as an integrated policy tool. Spatial planning is the process of reunderstanding and dividing regions through "space", and effectively integrating existing objects within this scope on the "space" platform.

The issue of climate change has comprehensive features, as it is not only an environmental science issue, but also a socio-economic issue that involves numerous sectoral fields. Therefore, to improve the effectiveness of climate change response actions, it is necessary to implement cross system and comprehensive multi-departmental response plans. This means that in the field of addressing climate change, it is necessary to achieve coordination of multiple goals and actions, which coincides with the role of spatial planning. Moreover, spatial form and climate change factors are closely related. As an important policy tool for coordinating spatial layout, optimizing spatial form, allocating land resources, and laying out infrastructure, spatial planning incorporates strategies related to climate change mitigation and adaptation into spatial planning [4]. It is an important means to solve climate change problems from a multi-

level perspective, while leveraging the integration role of spatial planning, achieving the compatibility of multiple goals and actions in addressing climate change.

This review will focus on the practical progress of implementing spatial planning in addressing climate change in the European Union and some member states, analysing the mitigation and adaptation strategies in spatial planning, clarifying the ways and key points of integrating spatial planning with climate change strategies. It summarises EU practical experience and concludes itself with recommendations and suggestions.

Cityscape, Berlin, Germany

2. Strategies for Addressing Climate Change in EU Spatial Planning

2.1 Implementation of EU Spatial Planning

The spatial structure of Europe is highly diversified, and EU countries have significant differences in natural resource conditions, economic and technological development levels, population structure, and urbanization levels. They have different planning cultures and macro environments, and face different issues in climate, environment, energy, land use, and other aspects. The EU's spatial planning cooperation is conducted at the three levels of Europe, national, and regional/local levels to ensure the greatest inclusivity, diversity, sustainability, the general improvement of quality of life, human rights, natural rights, and peace among people in Europe [5].

Driven by economic globalization, international economic cooperation and exchanges are constantly deepening, and the pace of regional integration is accelerating. There are significant differences in development levels among and within EU member states, with cities and regions exhibiting more dependence and competition. This competition may lead to uneven spatial development and threaten the integration of European society and economy. After the 1990s, the scope of the EU expanded eastward, leading to regional imbalances within the EU, hindering regional balance and sustainable spatial development, and increasing regional differences among most member states. Eliminating the imbalance in economic and social development among member states has gradually become a long-term goal of the European Union, while the increasingly severe environmental and resource issues and social stratification have brought in new spatial imbalances [6]. The closed and static traditional spatial development policies at the national and regional levels cannot adapt to the dynamic spatial pattern changes brought about by globalization and cannot manage planning issues that cross national boundaries. EU needs to coordinate and balance spatial development and achieve overall spatial planning.

2.1.1 European Spatial Development Perspective (ESDP)

In 1989, Europe launched an informal ministerial meeting on spatial planning, followed by the establishment of the Committee on Spatial Development (CSD) in 1991. At the Fourth CSD Conference in 1994, Germany, France, Denmark, and the Netherlands jointly proposed to develop a comprehensive blueprint for European space development. In 1999, European Commission officially issued the European Spatial Development Perspective (ESDP) [7], becoming Europe's first spatial planning policy document. As a guiding principle, ESDP does not have legal enforceability, but aims to guide the coordination and consistency of spatial development policies and sectoral policies, as well as closer cooperation among member states, cities, and regions, with the basic goal of strengthening the EU's socio-economic cohesion and achieving balanced sustainable development. Its main content includes two parts. The first part is the policy framework, and the second part is related analysis and background information, as shown in Table 1.

Table 1: ESDP framework

Part A Achieving the Balanced and Sustainable Development of the Territory of the EU: The Contribution of the Spatial Development Policy	Part B The Territory of the EU: Trends, Opportunities and Challenges
1. The spatial approach at European level 2. Influence of community policies on the territory of the EU 3. Policy aims and options for the territory of the EU 4. The application of the ESDP 5. The enlargement of the EU: an additional challenge for European spatial development policy	1. Spatial development conditions and trends in the EU 2. Spatial development issues of European significance 3. Selected programmes and visions for integrated spatial development 4. Basic data for the accession countries and member states

2.1.2 Study Program on European Spatial Planning (SPESP)

During the development of ESDP, the European Commission has conducted research on the evaluation criteria for distinguishing the composition of European regions. To improve the scientific basis of ESDP and enhance the scientificity of policy formulation, it is necessary to refine these criteria and the direction of spatial development. Therefore, the Study Program on European Spatial Planning (SPESP) was initiated in 1998. Its main purpose was firstly to conceptualize the standards proposed in ESDP for spatial differentiation, monitor the direction of European spatial development, and track the implementation of policy measures by establishing a quantifiable and complete evaluation index system (see Section 2.2.4 for details); The second is to visualize spatial policy objectives through charts; The third is to conduct experiments to establish the European Spatial Planning Observation Network (ESPON), and serve as the initial foundation of ESPON to carry out various cooperative researches and explore effective cooperation methods for the network, which involves the joint participation of member states[8,9].

2.1.3 Territorial Agenda of European Union (TAEU)

Following the ESDP, the EU introduced the Territorial Agenda of European Union (TAEU) [10] in 2007, which identified strengthening territorial cohesion as an important task for the EU and its member states in the future. TAEU includes the policy principles of ESDP, such as multi-center regional development, while also aligning with the goals of promoting EU economic growth and employment in the Lisbon Agenda. TAEU can be seen as the specific implementation of ESDP, and its most significant difference from ESDP is the shift from pursuing spatial balance to pursuing economic competitiveness. Its long-term goal had gradually shifted from eliminating the imbalance of economic and social development to promoting sustainable spatial development among member states and the concept of balanced development gradually weakened.

Through a review and update of the 2007 TAEU, the European Union introduced the Territorial Agenda 2020 (TA2020) [11] in May 2011. This new agenda established a policy framework based on the TAEU, emphasizing integrated development to enhance Europe's territorial cohesion.

Based on the review and update of TA2020, the EU launched the Territorial Agenda 2030 - A Future for All Places (TA2030) [12] at the end of 2020, which calls for strengthening sectoral policies at all levels of governance from the territorial spatial dimension and seeking ways to promote inclusivity and sustainable development, helping Europe achieve sustainable development goals and establish a just and green Europe. The new territorial challenges proposed in the three territorial agendas and the setting of policy priorities are shown in Table 2.

2.2 The Climate Change Strategies in EU Spatial Planning

2.2.1 Concept and Objectives

As the main document of the European Union's development plan and the first official document to officially propose "spatial planning", ESDP aims to achieve balanced and sustainable development as one of its fundamental goals. In its core, ESDP presents a multi-center balanced urban system, equal access to infrastructure and knowledge information system, and management and development of natural and cultural heritage. The fundamental goal and core content essentially clarifies the sustainable development concept of "spatial planning". Its focus on climate change issues is specifically manifested in: proposing that climate is a part of the environment and natural resources, and is collectively defined as one of the space development issues with European significance; emphasizing the role of spatial development policies in addressing climate change (especially in reducing traffic emissions and achieve energy conservation by renovating residential layouts), and making important contributions to climate protection by increasing the use of renewable energy and forest resources.

Also, in the TAEU, climate change and sustainable development have always been regarded as important territorial challenges, and the focus on energy, biodiversity, and natural resources also reflects the correlation between spatial planning and climate change mitigation and adaptation work. The TAEU emphasizes that each region and city can contribute to energy conservation, decentralized supply, and climate change mitigation through active participation, such as supporting the construction of low and zero emission communities, developing potential renewable energy supplies, and improving energy efficiency. This highlights the need for regions and cities to enhance resilience in the context of climate change. TA2020 emphasizes that different regions in Europe face different impacts and vulnerabilities to climate change. As the risks of sea level rise, drought, desertification, floods, and other natural disasters increase,

differentiated regional response measures are needed. Each region has opportunities to incorporate climate mitigation and adaptation into regional strategies and transition to a low-carbon economy. In addition, it has clarified the potential and opportunities for territorial development that climate change may bring, such as the importance of policy coordination in territorial space, especially in areas such as green economy, renewable energy production, water resource management, agriculture, housing, tourism, and transportation.

Table 2: Comparison of challenges and policy priorities in TAEU, TA2020, and TA2030

	TAEU	TA2020	TA2030
New Territorial Challenges	1. Regionally diverse impacts of climate change on the EU territory and its neighbours, particularly regarding sustainable development 2. Rising energy prices, energy inefficiency and different territorial opportunities for new forms of energy supply 3. Accelerating integration of our regions, including cross-border areas, in global economic competition, and at the same time increasing dependencies of states and regions in the world 4. Impacts of EU enlargement on economic, social, and territorial cohesion, particularly regarding the transport and energy infrastructure related integration of Eastern Europe and the new EU member states as well as their regions 5. Overexploitation of the ecological and cultural resources and loss of biodiversity, particularly through increasing development sprawl whilst remote areas are facing depopulation. 6. Territorial effects of demographic change (especially ageing) as well as in and out migration and internal migration on labour markets, on the supply of public services of general interest as well as the housing market, the development of the settlement structure and how people live together in our cities and regions	1. Increased exposure to globalisation: structural changes after the global economic crisis 2. Challenges of EU integration and the growing interdependences of regions 3. Territorially diverse demographic and social challenges, segregation of vulnerable groups 4. Climate change and environmental risks: geographically diverse impacts 5. Energy challenges come to the fore and threaten regional competitiveness. 6. Loss of biodiversity, vulnerable natural, landscape and cultural heritage	**Population and economic and social challenges:** 1. Quality of life 2. Services of general interest 3. Demographic and societal imbalances 4. Digitalization and the 4th industrial revolution 5. Employment and economic development 6. Interdependencies between places 7. Global embeddedness **Challenges in sustainable development and climate change:** 1. Climate change 2. Loss of biodiversity and land consumption 3. Air, soil, and water quality 4. Secure, affordable, and sustainable energy 5. Just transition 6. Circular Value Chain 7. Nature, landscape, and cultural heritage

Policy Priorities	1. Strengthening polycentric development and innovation through networking of city regions and cities 2. New forms of partnership and territorial governance between rural and urban areas 3. Promoting regional clusters of competition and innovation in Europe 4. Supporting the strengthening and extension of trans-European networks 5. Promoting trans-European risk management including the impacts of climate change 6. Strengthening of ecological structures and cultural resources as the added value for development	1. Promoting polycentric and balanced territorial development 2. Encouraging integrated development in cities, rural and specific regions 3. Territorial integration in cross-border and transnational functional regions 4. Ensuring global competitiveness of the regions based on strong local economies 5. Improving territorial connectivity for individuals, communities, and enterprises 6. Managing and connecting ecological, landscape and cultural values of regions	**A Just Europe:** 1. Better balanced territorial development utilising Europe's diversity 2. Convergent local and regional development, less inequality between places 3. Easier living and working across national borders **A Green Europe:** 1. Better ecological livelihoods, climate-neutral and resilient towns, cities, and regions 2. Strong and sustainable local economies in a globalized world 3. Sustainable digital and physical connectivity of places

2.2.2 Action Measures

TAEU has proposed specific action measures for climate change and sustainable energy development in the policy priorities, as shown in Table 3.

In TA2020, specific action measures were proposed for issues such as agricultural and forestry resource protection, renewable energy utilization, and natural and cultural resource protection among policy priorities, as shown in Table 4.

In TA2030, the priority of "building resilient towns, cities, and regions with better ecological environment and climate neutrality" proposes corresponding action measures in three areas closely related to climate change adaptation, namely ecosystems, climate change and biodiversity, and natural and cultural heritage, as shown in Table 5.

Central location in Bern, Switzerland, ©Pexels

Table 3: Climate change related action measures proposed in TAEU

Priorities	Action Measures
Support for strengthening and expanding the pan- European network	Considering the limited reserves of non-renewable energy, as well as the import energy dependence and climate change challenges faced by the EU, it is necessary to accelerate the exploration and development of decentralized, efficient, safe, and environmentally friendly renewable energy production, and make good use of the potential of regions, especially rural areas, in the energy sector.
Promoting Pan-European Risk Management	Developing cross regional comprehensive methods and strategies to respond to natural disasters, reducing greenhouse gas emissions, adapting to climate change, and further developing and strengthening territorial cohesion policies based on regional differences. To improve the efficiency of risk management, comprehensive strategies across Europe and borders are adopted, such as flood control, drought and desertification prevention, integrated management of coastal and mountainous areas, technological disaster management, disaster prediction, etc., and new forms of risk management strategies are developed.
Strengthening ecological structure and cultural resources as added value for development	Emphasizing the importance of ecological structure, advocating the creation of a sustainable trans-European green structure, establishing appropriate corridors and regions between protected areas and other regions, and forming a green network, is to some extent one of the important concerns for adapting to climate change.

Table 4: Climate change related action measures proposed in TA2020

Priorities	Action Measures
Encouraging integrated development of cities, rural areas, and specific regions	In rural areas where farmland and forest land are important forms of land use, support the protection of high-quality farmland and ecological functions.
Improving regional connectivity among individuals, communities, and businesses	Supporting the production and use of decentralized, efficient, safe, and environmentally friendly renewable low-carbon energy
Managing and connecting the ecological, landscape, and cultural values of various regions	1. Joint risk management to support the integration of ecosystems and natural value reserves into green infrastructure networks at all levels. 2. Protecting and developing the natural and cultural landscape values of European cities and rural areas, creating environmentally friendly employment opportunities, strengthening recreational functions to achieve complementary protection, implementing regional and cross regional management of cultural and natural heritage, and protecting local and regional natural and cultural resources by enhancing local and regional awareness and responsibility for their unique environmental, landscape, cultural, and other values.

Table 5: Climate change related action measures proposed in TA2030

Priorities	Fields	Action Measures
Better ecological livelihoods, climate-neutral and resilient towns, cities, and regions	Ecosystems, including agriculture, forest, grassland, fresh water, and marine ecosystems	1. Implementing protection measures for ecosystems to ensure and enhance sustainability, functionality, and resilience in response to climate change and the loss of biodiversity 2. Ensuring the supply of ecosystem services 3. Raising public awareness 4. Developing natural based solutions to build green (landscape) and blue (water) infrastructure networks that connect ecosystems and protected areas in spatial planning, land management, and other policies 5. Developing new disaster management tools to enhance local security and resilience
	Climate change and biodiversity	1. Developing climate neutral urban and regional strategies 2. Promoting sustainable land use 3. Open spaces and public green spaces 4. Restoration of degraded land and coastal areas 5. Combating deforestation 6. Protecting the ocean and water bodies 7. Preventing urban sprawl and urban heat island effects 8. Building green infrastructure 9. Improving air quality 10. Integration of land and ocean spatial planning
	Natural and cultural heritage	1. Balancing natural conservation, sustainable use of natural resources, and economic development, including creating environmentally friendly employment opportunities, promoting community growth and well-being, or collaborating with innovative social entrepreneurs 2. Protecting, restoring, and utilizing the environment, landscapes, material, and intangible cultural assets, as well as other unique values through EU cohesion policies, rural development policies, spatial planning, or other policy tools that promote comprehensive territorial or local development

2.2.3 Technical Tools

To further promote the implementation of ESDP, the European Union has established the European Spatial Planning Observation Network (ESPON) based on SPESP. Starting from 2002, a series of projects have been carried out to measure key indicators such as population, economy, infrastructure, and innovation capacity in EU member states, as well as in Iceland, Liechtenstein, Norway, and Switzerland. The projects have provided evaluations and predictions of the status and trends of spatial development in these countries, and a large amount of data information for the implementation of ESDP.

In 2020, the ESPON 2030 Program [13] was released, proposing seven Thematic action plans (TAPs), which are closely related to the EU's cohesion policy goals for 2021-2027 and the priorities of the 2030 territorial agenda. Among them, four themes are prioritized, including Climate Neutral Territories, Governance of New Geographies, Places Resilient to Crises, and Perspectives for All People and Places. Under the overall framework of ESPON, several research projects [14-18] involve supporting climate change mitigation or adaptation efforts at the spatial level, as shown in Table 6.

Table 6: Content related to addressing climate change in ESPON 2030 Program

ESPON-CLIMATE Project	**Objectives** Producing evidence to understand how and to which degree climate change may impact the competitiveness and cohesion of European regions and Europe as a whole. Analysing how policies can help mitigate climate change, adapt to, and manage unavoidable climate change outcomes. Ensuring the use of synergies between mitigation and adaptation policies. **Achievements or Expected Accomplishments** Outcome 1: Identification of 8 climate impact chains · Heat stress on population, · Coastal floods on infrastructure, industry, and service sectors, · River floods on populations, · River floods on infrastructure, industry, and service sectors, · Flash floods on cultural sector, · Wildfires on the environment, · Droughts on primary sector, · Aggregated risk Outcome 2: Aggregated risk of climate change The pattern of risks from climate induced hazards for baseline scenario in the European regions is very similar to the ones obtained in the low-emissions scenario (2070-2100 RCP2.6), with higher risk in Southern Europe and lower risk in Northern Europe. Outcome 3: Risk assessment of individual impact chains The impact chain related to temperature and water resource availability shows a risk gradient of high in the south and low in the north, with Romania, Bulgaria, Greece, Italy, Spain, and Portugal being significantly affected; In the impact of river floods, the Netherlands, France, UK, Ireland, and Sweden are more affected; The impact of coastal floods on the Netherlands is significantly higher than that of other countries.
ESPON-TITAN Project	**Objective** Providing pan-European evidence of direct and indirect economic losses caused by natural disasters at the territorial level, and evaluate the effectiveness and effectiveness of tools related to disaster risk management and climate change adaptation measures (used for spatial planning/territorial development) to determine the best risk management and adaptation strategies. **Achievements or Expected Accomplishments** A method for assessing the economic impact of natural disasters has been developed, which consists of two steps: Step 1: A large-scale European assessment using existing data covering Europe Step 2: A more centralized assessment focusing on regional/local scales. It involves natural disasters such as floods and landslides, water scarcity, droughts, storms, and earthquakes
ESPON-LOCATE Project	**Objectives** Quantitative assessment of energy consumption patterns and the potential for the production and use of renewables in various regions; Qualitative analysis of energy related policies at the regional level, as well as coordination with policies at the national and EU levels; Suggestions for formulating low-carbon economic transformation policies by integrating the perspectives and needs of policies at various levels. **Achievements or Expected Accomplishments** Outcome 1: Identified the regional pattern of energy consumption, renewable energy application, and development potential, and evaluated the low-carbon economic transformation potential of the region. Outcome 2: Through case studies, identified the key to achieving low-carbon economic transformation at the regional level and identified effective regional actions and policy measures. Outcome 3: Clarified the supporting role of European cohesion policies in achieving low-carbon economic transformation in the region.

2.2.4 Evaluation Indicators

Through ESDP and SPESP, Europe has established a system of spatial development evaluation indicators. ESDP proposed 7 criteria for spatial development evaluation, and SPESP further developed them into quantifiable indicators in 7 categories, namely geographical location, spatial integration, economic strength, natural resources, cultural resources, land use pressure, and social integration. The categories of "natural resources" and "cultural resources" include indicators related to climate change adaptation, as shown in Table 7.

Table 7: Climate change related indicators in the EU spatial development evaluation standards and indicator system

Evaluation Standards (ESDP)	Definition	Evaluation Indicator (SPESP)
Natural resources	The importance, sensitivity, scale, or rarity of ecosystems and other natural fields	Environmental pressure, pollution gas emissions, water quality, coastal value, ecosystem diversity, biodiversity, natural disasters, potential productivity, natural resource threats, and classification of protected areas
Cultural resources	The importance, sensitivity, scale, or rarity of natural landscape features and ancient and modern cultural architecture	Cultural landscape indicators: importance index (proportion of farms with less than 20 hectares of agricultural land, agricultural output, and annual number of tourists), threat level index (population change, length of transportation network, marginal benefits of agricultural land); diversity index Cultural heritage indicators: absolute number of cultural heritages per unit area; tourist capacity; and proportion of annual tourists to local residents

2.3 The Significance and Impact of EU Spatial Planning System

The European Union's spatial planning concept has gradually evolved from the development of previous planning concepts, combined with the background of global social development, and kept pace with the times [19]. Although its planning concept is not entirely newly developed, it has formed a new model of "spatial integration platform". The emergence of spatial planning demonstrates that regional strategies can help coordinate actions between different departments. By integrating policies in different fields at the spatial level, conflicts and contradictions between policies are avoided, emphasizing cohesion and balanced sustainable development. This has also had a certain impact on the construction of policy planning systems in EU countries.

Firstly, the EU has integrated and created structural funds, including the European regional development fund (ERDF), European social fund (ESF), and Cohesion fund, to implement regional policies. Economic means have provided motivations for member states, that they need to ensure their spatial planning is coordinated and consistent with EU policies, to entitled to EU's funding in infrastructure construction, investment and job creation, and regional cooperation in resource management.

Secondly, the introduction of EU spatial planning system and the policy framework has prompted member states to re-examine their own planning systems, thereby updating domestic policy and promoting planning changes. For example, EU member states, such as Germany and the Netherlands, have prioritized European backgrounds in their country spatial development plans.

Thirdly, the EU's spatial planning promotes communication and cooperation at different spatial scales on issues of common concerns through various action plans. This cooperation not only requires coordination of policies among countries and regions, but also requires collaboration among different departments. Therefore, it promotes overall coordination and cooperation in EU on a large scale, solving policy and interest conflicts in planning systems horizontally and vertically. Meanwhile, the coherence and complementarity of the spatial development planning systems of member states have also been strengthened.

Lastly, in terms of climate change strategies, the EU's spatial planning has given EU-level priorities and considerations on the concepts and objectives, action measures, technical tools, evaluation indicators, etc. That has played a certain guiding role in the formulation of member states' spatial planning. Within the concept and action framework of the EU, member states should formulate more effective action goals, strategic measures, indicator systems, etc., considering their own features and difficulties in addressing climate change.

3. Strategies for Addressing Climate Change in EU National Spatial Planning

3.1 Germany

3.1.1 Implementation of Spatial Planning in Germany

Germany is one of the earliest countries in the world to carry out spatial planning, and the legal basis of its spatial planning system can be traced back to the Saxony Building Act of 1900. Afterwards, in 1960, the Federal Building Act (Bundesbaugesetz) was promulgated, regarded as the starting point of German urban planning legislation. Subsequently, the Spatial Planning Act (Bundesraumordnungsgesetz) [20] was passed in 1965, the Urban Construction Promotion Act (Staedebaufouderungsgesetz) was promulgated in 1971, and by 1987, the Federal Building Act and the Urban Construction Promotion Act were merged and adjusted to the Building Code (Baugesetzbuch)[21], becoming an important milestone in Germany's territorial spatial planning. Until now, the responsibilities, content and compilation principles of spatial planning are determined by the Spatial Planning Act and the Building Code. The German spatial planning system consists of four levels: national level, state level, regional level, and local level.

National level

Spatial Planning Act was formulated and came into effect in 1965 and was revised by the Federal Parliament in 1997. Spatial Planning Act is the legal basis for the planning of German federal spatial order, proposing the basic principles of guiding spatial planning based on the concept of sustainable development, dividing German national space according to different functions, and providing for the formulation of spatial planning legislation, planning methods, and implementation coordination in various regional states. Since German reunification, the three important national spatial planning documents released by the German federal government have been the Spatial Planning Policy Guidelines (Raumordnungspolitische Orientierungsrahmen, ORA) [22] released in 1993, the Space Development Concept and Action Strategy (Leitbilder und Handlungsstrategien für die Raumentwicklung in Deutschland) [23] released in 2006, and the updated version of the Space Development Concept and Action Strategy [24] released in 2016. Among them, the Guiding Framework for Spatial planning Policy in 1993 proposed key tasks from five aspects: settlement structure, environment and space utilization, transportation, Europe, and governance and development, clarifying the need for various regions of the federal government to integrate themselves into a unified European spatial model, and combining German policies with the EU structural funds, so that states can receive more EU funding [25]. The introduction of this document provides Germany with a new spatial development and strategic planning model. The two Space Development Concept and Action Strategy documents issued in 2006 and 2016 emerged in the process of the EU's transformation from a focus on balanced development to a focus on sustainable development after the 21st century. The 2016 version proposed four major development principles, including enhancing competitiveness, ensuring public services, land use regulation and sustainable development, and addressing climate change and shaping energy revolution. Among these, addressing climate change and shaping energy revolution was first proposed as one of the principles. Furthermore, to ensure the compatibility between renewable energy development and spatial planning goals, and reserving space for renewable energy development, this document indicates the distribution of existing key areas for renewable energy (including wind power, solar power, biomass power, hydropower), traditional energy production (including coal, gas, nuclear energy), and transmission network channels in the entire space. It proposes phased development strategy, the approaches on site selection and land use for minimizing conflicts and reducing the demand for grid expansion, as well as the approaches on grid expansion for the distribution of renewable energy consumption. There are differences in planning background, concept, and actions between the two versions, as shown in Table 8.

Table 8: Comparison between Space Development Concepts and Action Strategies of 2006 and 2016

	Space Development Concept and Action Strategy (2006)	Space Development Concept and Action Strategy (2016)
Planning Background	1. The strengthening of the European integration process requires Germany's space development policy to take on new responsibilities in continuously improving international cooperation. 2. Globalization has intensified economic competition and had a negative impact on the environment. 3. The impact of population decline, aging population, and increased immigration on spatial utilization 4. The increasingly narrow fiscal operating space and the global trend of privatization and economic liberalization have led to changes in national regulatory measures.	1. Population changes have had an impact on residential areas and infrastructure structures. 2. Mitigation and adaptation strategies for climate change should be incorporated into spatial planning. 3. The energy revolution has led to the expansion of renewable energy, generating space demand. 4. Public participation tools have been further developed to enhance public acceptance of the planning process. 5. Digital infrastructure has had impacts on public services and economic development. 6. The increasingly narrow financial activity space requires the concentration of core tasks, as well as new financial support and organizational plans, including various forms of cooperation between local and departmental levels. 7. The EU cohesion policy demands balanced development. 8. Ocean spatial planning is a responsibility at the EU, federal, and state levels. 9. The contradiction between land use requirements and protection requirements related to space is becoming increasingly acute. 10. Globalization has brought about more efficient and powerful transportation and logistics systems, which have had an impact on the transportation system.
Concept and Action Strategy	1. Growth and innovation: The federal government needs to develop development strategies that have significant spatial significance, fully utilize existing growth and innovation potential, and are in line with sustainable development principles. 2. Ensuring equalization of public services: ensure the quality of public services and clarify multi-center solutions. 3. Protecting resources and shaping cultural landscapes: Balance land needs, protect open spaces and natural resources, and manage cultural landscapes.	1. Enhancing competitiveness: continue to develop metropolitan areas, strengthen collaboration and networking between regions, support the development of areas with special structural action needs, and ensure infrastructure connectivity and mobility 2. Ensuring public services: continue to adopt a central system, expand cooperation, ensure public services in sparsely populated rural areas, and ensure accessibility 3. Land use regulation and sustainable development: minimize land use conflicts, create a large-scale open space network, shape cultural landscapes, reduce land occupation, sustainably utilize mineral resources and other underground spaces, and sustainably utilize coastal zones and oceans 4. Addressing climate change and shaping the energy revolution: spatial structure should adapt to climate change, expand the use of renewable energy, and expand its network.

In addition, the federal government regularly prepares a Spatial Planning Report to explain the status and trends of space development within the federal region, implementation plans and measures, the regional impact of EU and federal policies, and the impact of European integration on Germany's space development. The reports of Spatial planning consist of two parts. The first part is "Space Development", which elaborates on the concept of spatial planning; the second part is "Planning and Measures with Spatial Significance", which introduces the planning and measures with spatial significance adopted during the reporting period.

State and regional levels

At the state and regional levels, it is stipulated that state governments can independently prepare state plans (Landesplanung) at the federal state level and regional plans for certain regions of the state (Regionalplanung).

State level spatial planning is called the State Development Plan, which coordinates the spatial planning laws and policies with spatial impact within the state's jurisdiction, targeting the spatial planning goals of the state. Like national-level planning, state level planning needs to reserve space for climate protection action plans centered on renewable energy [26]. The planning generally includes the current development status of the state, the spatial structure and planning concept of the state, the structure of urban settlements, the open space structure and safety of open space, urban planning, transportation, protection and development of the natural environment, agriculture and forestry, energy production and services, water supply and drainage, garbage treatment, and other aspects.

Regional planning is a spatial planning that goes beyond a central town but does not cover the entire state territory. It is a planning level between the state level and the local level. Regional planning not only includes the goals related to the region in state level planning, but also makes provisions with cross regional significance in terms of central land system, residential structure, cross regional transportation lines and infrastructure, natural reserves and landscape protection areas, forest areas and afforestation areas, agricultural land use areas, regional green belts, climate protection areas and flood control and detention areas, raw material mineral protection areas or mining areas, cultural relics protection facilities, etc.

Local level

The federal level planning, state level planning and regional level planning tend to be more strategic, while the local level planning tends to be more focused on implementation. The local level planning is called construction guidance planning (Bauleitplanung), including land use planning (Flaechennutzungsplan) and construction planning (Bebaungsplan). Cities and towns formulate corresponding planning according to the needs of urban and rural construction and development, and the goals of construction guidance planning should be consistent with the goals of regional planning [21].

Land use planning is a preparatory construction guidance planning (vorbereitender Bauleitplan). Its responsibility is to plan the types and scale of land use within the city, as well as the layout of renewable energy generation facilities, energy supply networks, and municipal public facilities based on the strategic goals of urban development and land needs. Land use planning explains the relevant areas that include measures to address climate change, especially production facilities, energy supply networks, energy storage devices for decentralized and centralized renewable energy or cogeneration, as well as waste and sewage treatment areas, green spaces, mineral resource extraction areas, agricultural land, forests, and areas used for soil and natural landscape protection and development[21], providing policy support for the coordinated development and network construction of climate resources and renewable energy. In addition, land use planning specifically indicates areas that require special structural prevention measures to resist natural disasters, areas where mineral resources are planned to be mined, and construction land severely polluted by harmful environmental substances.

Construction planning is a mandatory guidance plan (verbindlicher Bauleitplan) that is formulated based on land use planning and including legally binding provisions for urban planning. The construction planning includes regulations and descriptions, and series of legal indicators to regulate specific areas such as areas for renewable energy supply, waste and sewage treatment, and areas that require special structures or technical measures to prevent flooding, green spaces, agricultural land, forests, and others.

3.1.2 Strategies For Addressing Climate Change in Spatial Planning

Concepts and Principles

National legislation and spatial planning primarily focus on formulating concepts and principles, such as the Spatial Planning Act, which emphasizes the basic principles of "protecting, maintaining, and developing nature, countryside, water bodies, and forests; maintaining or restoring the functions of long-term idle land; protecting the coast and inland to prevent floods, especially protecting or restoring vegetation, buffer areas, and areas damaged by floods", Not only does it comply with the concepts and goals of the EU, but it also lays the foundation for the subsequent preparation of spatial development plans on national, state, regional, and local level.

Afterwards, the Spatial Planning Policy Guidance Framework clarifies that protecting the environment is the foundation for achieving sustainable space utilization, and it is necessary to effectively address the conflict between development and protection. In densely populated areas, it is required to improve open spaces and protect important areas of natural landscapes and water resources; In areas with severe environmental pollution, it is required to reduce environmental damage and carry out ecological restoration; propose the establishment of a protection network system for landscapes and community habitats, measure structurally weak areas based on ecological indicators, arrange work and residential areas reasonably, and avoid new environmental loads[25]. The Space Development Concept and Action Strategy of 2006 proposed the concept of "protecting resources and shaping cultural landscapes", while the Space Development Concept and Action Strategy of 2016 further proposed the integration of ocean space into spatial planning and included "addressing climate change and shaping the energy revolution" as one of the sustainable development concepts in spatial planning.

Actions

As mentioned earlier, the Space Development Concept and Action Strategy of 2006 proposed corresponding action strategies around the concept of "protecting resources and shaping cultural landscapes". These strategies are implemented through state and regional planning, residential land management and reducing construction land demand, river landscape and flood control, spatial planning of territorial waters and exclusive economic zones, and integrated coastal zone management.

The Space Development Concept and Action Strategy of 2016 has been supplemented, refined, and extended on this basis, providing a key response to the highly focused international issue of "addressing climate change and shaping the energy revolution". In addition, the document identifies key priority areas for renewable energy nationwide, namely areas with high-installed capacity for wind, solar, biomass, and hydropower. It explicitly proposes that spatial planning policies should ensure the compatibility of renewable energy development with spatial planning goals, providing a basis for implementing federal greenhouse gas emission reduction goals and action plans. It also guides the implementation of climate protection goals and energy strategy goals in spatial planning for various states.

In addition, since 2008, German government departments have been committed to promoting the implementation of the German Strategy for Adaptation to Climate Change (Die Deutsche Anpassungsstrategie an den Klimawandel) [27] and updated the document in 2015 and 2020[28]. This document emphasizes that climate adaptation is a key component of urban spatial development planning, advocating for the adjustment and improvement of laws and planning tools to promote the improvement of adaptability to climate change and the resilience optimization of urban spatial structure. The specific consequences and corresponding action plans of future climate change on 15 action areas (human health, building sector, water regime, water management, coastal and marine protection, soil, biological diversity, agriculture, forestry and forest management, fishery, energy industry (conversion, transport, and supply), financial services industry, transport and transport infrastructure, trade and industry, tourism industry) were described. In addition, this document clarifies that spatial, regional, and physical development planning can play a leading role by developing adaptive and resilient spatial structure models, supporting spatial structures to respond effectively and flexibly to social changes, which is of great significance for climate change adaptation. Specific measures are proposed, as shown in Table 9.

Table 9: Spatial planning measures in German Strategy for Adaptation to Climate Change

Significance	Regions/Fields	Measures
Providing for risks by adapting to the expected increase in the intensity and frequency of extreme weather situations	River basin	Plan flood storage areas (as priority and reserve areas for flood control), improve flood control standards based on the 200-year flood, protect existing flood discharge and detention areas, and prepare for necessary expansion.
		Conduct sufficient and dispersed rainwater infiltration in the river catchment area. Reduce the occupation of open land by newly built residential buildings and infrastructure, provide planning support for ecological restoration and re greening of land, ensure appropriate agricultural use, and improve the natural absorption capacity of rainfall.
	Coastal areas and islands	Carry out embankment construction and renovation and develop new forms of safety prevention measures for islands and coasts, especially passive prevention measures.
	Mountain ecosystem	Develop planning and preventive measures for natural disasters such as mudslides, rockfalls, and soil erosion.
	Densely populated areas	For densely populated areas, to reduce the impact of high temperature heatwaves and heat island effects, it is necessary to carry out close cooperation between cities and their hinterland and implement small-scale climate adaptation strategies.
Adaptation to landscape change and restrictions on the usability of natural resources	Groundwater	If the groundwater recharge rate decreases due to climate impact, leading to a shortage of regional water resources, it is necessary to strengthen regional planning of water resources to ensure the proper utilization of water resources.
	Oceans and coastal zones	The rise of groundwater levels related to sea level and the worsening trend of coastal erosion require more efforts to protect coastal areas and create conditions for the development of coastal landscapes.
	Tourism	Set up spatial adaptation measures for the tourism sector from the perspective of spatial planning, especially in coastal and mountainous areas, with emphasis on reinvestment and new infrastructure, and use demonstration area planning projects to support the development of climate change adaptation concepts.
	Species protection	Providing planning support for the protection of nature reserves and composite ecosystems, regional planning can effectively contribute to species' adaptation to habitat changes caused by climate change.

Technical Tools

As one of the specific implementation methods of strategies on national level planning, state level and regional planning will adopt specific technical approaches to promote the implementation of state, regional, or local planning. Most states have developed climate protection plans or action plans as supplements to national policies and provide incentives in specific action areas, such as Saxony, North Rhine Westphalia, Baden Wurttemberg, and other states emphasizing the promotion of renewable energy development; Some states have also made deployments in their respective key emission areas, such as supporting the modernization of fossil fuel power plants to reduce carbon emissions caused by fossil energy production. The state development plan of Rhineland Pfalz is explained an example [26]. The plan has marked key wind energy utilization areas, key areas with high wind power potential, and key areas with high global solar radiation potential by drawing a distribution map of renewable energy and evaluating the distribution areas of renewable energy potential within the state, to lay the foundation for the rational development and utilization of renewable energy in regional and municipal planning.

Regarding the land use planning on the local level, a land use planning map is developed to plan and arrange several types of land use within the city. The key areas for renewable energy use such as wind energy, photovoltaic energy, biomass, as well as natural disaster resistance and environmental pollution prevention and control are specially marked, serving as a reference for other relevant departments' plans and major engineering construction.

3.1.3 Summary

Key aspects of the climate change strategies in Germany's spatial planning are set out below:

Firstly, concepts and actions will dynamically adjust with changes in the socio-economic development stage and reflect the implementation of the EU's spatial development policy. The strategy of addressing climate change in German spatial planning has experienced three stages of the times. In the 1970s, German spatial planning reflected the concept and actions of addressing climate change from the perspective of environmental protection, with the fundamental purpose of protecting various environmental elements from the impact of development. In the 1990s, influenced by the EU's goal of promoting balanced development, Germany's concept of addressing climate change in its spatial planning placed greater emphasis on environmental sustainability, including measures such as ecological restoration to enhance climate resilience. Since the 21st century, globalization has further intensified, and the EU's concept of "balanced development" has been more replaced by "sustainable development". In Germany's strategy to address climate change, attention has been given to the protection of cross-regional natural resources and cultural landscapes, and to the importance of sustainable use of marine resources. In line with prioritized topics on international agenda, the concept of "addressing climate change and shaping the energy revolution" has been proposed with the corresponding measures on the use of renewable energy and greenhouse gas emissions reduction. That is reflecting the adaptation of Germany's climate strategy in its spatial planning to international and EU environmental changes.

Secondly, spatial planning provides an adaptive and resilient spatial structure model, achieving the nesting of spatial and climatic elements. In the German Strategy for Adaptation to Climate Change, corresponding spatial planning schemes were proposed for different regional types and climate disaster types. This is an effective form of integrating actions from different departments in the same space by combining fragile areas and regional identification, typical risk identification, and achieving visual distribution and the spatialization of climate factors and the corresponding management measures.

Thirdly, spatial planning at various levels in the German spatial planning system involves a high degree of coordination, and each has its own focus with clear goals and responsibilities. Each level of spatial planning must consider the spatial planning of its upper level and participate in its preparation. The national level planning is responsible for providing guidance on environmental protection, natural disaster prevention and control, resource protection and energy use, and concepts and principles on addressing climate change. It also proposes strategies and implementation approaches for relevant issues, identifies key areas and regions, and supplies guidance for each state to incorporate climate change strategies into its spatial planning. The state and regional level play a connecting role in implementing national concepts and principles, and putting the action strategies and means proposed by the federation into specific implementation stages. The state level is responsible for determining the development structure of the state (such as land use structure, energy zoning, etc.), formulating principles and setting relevant indicators, coordinating and determining the development direction and tasks of each region; the regional level is responsible for implementing regional delineation and indicator transmission, coordinating and determining the development direction and tasks of each city. The land use planning and construction planning at the local level is responsible for providing more detailed scope delineation and timing determination for tasks designated from the state and regional levels.

3.2 Netherlands

3.2.1 Implementation of Spatial Planning in the Netherlands

The spatial planning in the Netherlands consists of three levels: national level planning, provincial level planning, and local level land use planning. At the beginning of the 20th century, the Netherlands began to attach importance to national spatial planning, utilizing overall spatial strategies to plan and regulate national resources. In 1958, the Netherlands compiled the Randstad Development Plan, laying an important foundation for national spatial planning in the Netherlands, and proposing protection and implementation strategies for the "green heart" area[1]. From 1960 to 2004, the Government of the Netherlands promoted the preparation of five national spatial planning policy documents. The focus of planning gradually ranges from addressing fairness and efficiency issues in the development process of the Netherlands to balancing economic development and ecological environment protection and improving spatial quality. A national spatial development model controlled by the "green heart" and centered around urban areas and national urban networks has been gradually formed [29], taking in the importance of sustainable concepts in national spatial planning.

In 2006, the National Space Strategy (Nota Ruimte) was released, based on extensive consultation and recommendations on the Fifth National Spatial planning Policy Document and its supplementary document - Key Decisions in National Spatial planning, and integration of the Fifth National Spatial Planning Policy Document, the Second National Green Area Structure Plan, and the National Transportation Plan. In 2008, the Government of the Netherlands revised the Spatial Planning Act of 1965, simplifying the preparation process and replacing the previous "spatial planning policy document" with "structural vision". In the same year, Randstad introduced a space development strategy for 2040 - Structural Vision Randstad 2040 (Structuruvisie Randstad 2040). This document proposes 12 important spatial strategic decisions for the spatial development of Randstad in 2040, including "building a safe and climate resistant green (landscape) blue (water) delta". The introduction of this document has also made the development of open spaces and green structures a major highlight of the spatial planning system in the Netherlands. In 2010, the Ministry of Housing, Spatial Planning, and Environment officially disintegrated, and the functions of spatial planning were merged into the newly established Ministry of Infrastructure and Environment (renamed as the "Ministry of Infrastructure and Water Management" in 2017). In 2012, the Ministry of Infrastructure and Environment issued the Infrastructure and Spatial Structure Vision 2040 report, which comprehensively replaced several national policy documents, including the previous round of national spatial planning report, and key regional planning document such as Randstad Structure Vision 2040 and National Transportation Strategy and Policies.

Due to its abundant water resources, the Netherlands is bordered by the North Sea to the west and north and is in the delta plain where the Rhine, Meuse, and Schelder rivers intersect. It is a typical lowland country, with one-third of its land below sea level and an elevation of less than one meter. Except for some hills in the south and east, the majority of the land is low and is at any time in danger of seawater flooding, as well as the floods caused by the Rhine and Maas rivers. Therefore, the Netherlands is highly vulnerable to the impact of climate change and has become one of the countries that attach the most importance to climate change globally.

In Netherlands, open space and green structures are national features, and water governance and climate resilience are crucial factors affecting national security. They run through all levels of spatial planning and have formed a unique climate strategy that is integrated with spatial planning.

3.2.2 Strategies for Addressing Climate Change in Spatial Planning

National level

The National Space Strategy 2006 of the Netherlands set up the spatial development vision until 2020, clarifying that the main impacts of climate change on spatial development in the Netherlands are increased winter floods, intensified summer droughts, and long-term increases in river and ocean water levels. It emphasizes that water governance is one of the basic starting points of the spatial planning process [30]. In the same year, the National Climate Adaptation and Spatial Planning (National Program Adaptatie Ruimte en Klimaat) was released, calling for attention to the long-term impacts of climate change and emphasizing that spatial planning can play a key role in resisting climate change. The location selection and spatial planning of new commercial, transportation, and energy security projects in the future may be affected by the need for climate adaptation and

1 The Randstad region as a key area in the spatial planning system in the Netherlands since the 1950s., is a typical multi center urban cluster that includes four major cities (Amsterdam, Rotterdam, The Hague, and Utrecht), the Randstad region has a clear circular distribution feature in terms of spatial structure. The central region of the region is mainly composed of agricultural space, known as the "green heart", and has long been responsible for the development of agriculture and water conservation, The major cities are distributed around the edge of the "green heart".

mitigation [31]. The release of these two documents emphasizes the urgency of adopting measures on climate adaptation and mitigation and clarifies the importance of combining spatial planning with water governance and addressing climate change.

In terms of water governance, the National Vision for Water Management, released in 2007, advocates that water is a decisive factor in spatial planning related to urbanization, economic development, industry, natural landscapes, and entertainment, and emphasizes that infrastructure, such as roads, urban networks, ports, etc. should have the ability to resist climate change [31]. The National Water Plan (Nationaal Waterplan 2016-2021) [32], issued in 2016, proposes to develop climate-adaptive spatial planning schemes around rainwater and inland flood safety, freshwater supply, and water quality improvement. It delineates and labels the layout of flood risk management facilities within the spatial area, such as repairing flood control systems, flood resistance systems, protecting coastal sand systems, and storm surge barrier maintenance systems. It maps out the areas with freshwater problems, including insufficient freshwater supply, salinization, low river water levels as well as climate- adaptive cities. It also analyses and identifies the issues caused by climate risks, such as sea level rise, soil subsidence, saline wedges, coastal erosion, river erosion and others, as shown in Figure 1.

The National Water Plan ((Nationaal Water Programma 2022–2027)) [33] issued in 2022 further clarifies that spatial planning should assess the vulnerability of an area under extreme climate conditions, especially the vulnerability of essential functions. In addition, the Netherlands has been releasing the Delta Program (Nationaal Deltaprogramma) annually since 2011. In terms of integrating water resource management, climate adaptation, and spatial development, the Delta Plan on Spatial Adaptation (Deltaplan Ruimtelijke adaptatie) has been developed with the goal of 'making all spatial plans in the Netherlands adaptive to climate change.' It proposes measurements such as the establishment of the pluvial and river flooding policy platform, the development of the national yardstick for a green climate-adaptive environment and the spatial assessment framework, the promotion of climate adaptation stimulus scheme, and the establishment of climate adaptation knowledge portal [34]

In terms of improving climate resilience, the Infrastructure and Spatial Structural Vision 2040 (Structuurvisie Infrastructuur en Ruimte, SVIR) [35] of 2011 has proposed to make the Netherlands more convenient, liveable, and safe. Based on the national spatial structure, key areas and structures of national importance are shown in the form of maps. It is shown on the map, including potential areas for power plants with a capacity of over 500MW and nuclear power plants, potential areas for sea land power grid connections, coastal basic management areas, basic flood control areas, natural and cultural heritage areas, and terrestrial ecological networks. The map reveals how national challenges are interconnected in the spatial structure, as shown in Figure 2. The purpose is to provide effective space for urban development for flood control, sustainable drinking water supply, and climate adaptation, in addition to protecting national and international unique cultural heritage and natural value areas, natural habitats, and biodiversity through the construction of national ecological networks. In 2016, the National Adaptation Strategy (Nationale klimaatadaptatiestrategie) [36] was released, emphasizing the use of land and spatial planning to adapt to disasters caused by climate change, enabling the Netherlands to achieve climate proof and ensure normal operation in the face of uncertain disasters. This document has proposed climate adaptation measures from various aspects including awareness, practical application, risk management, policy legislation, monitoring system, etc. Some highlights of these measures are shown in Table 10.

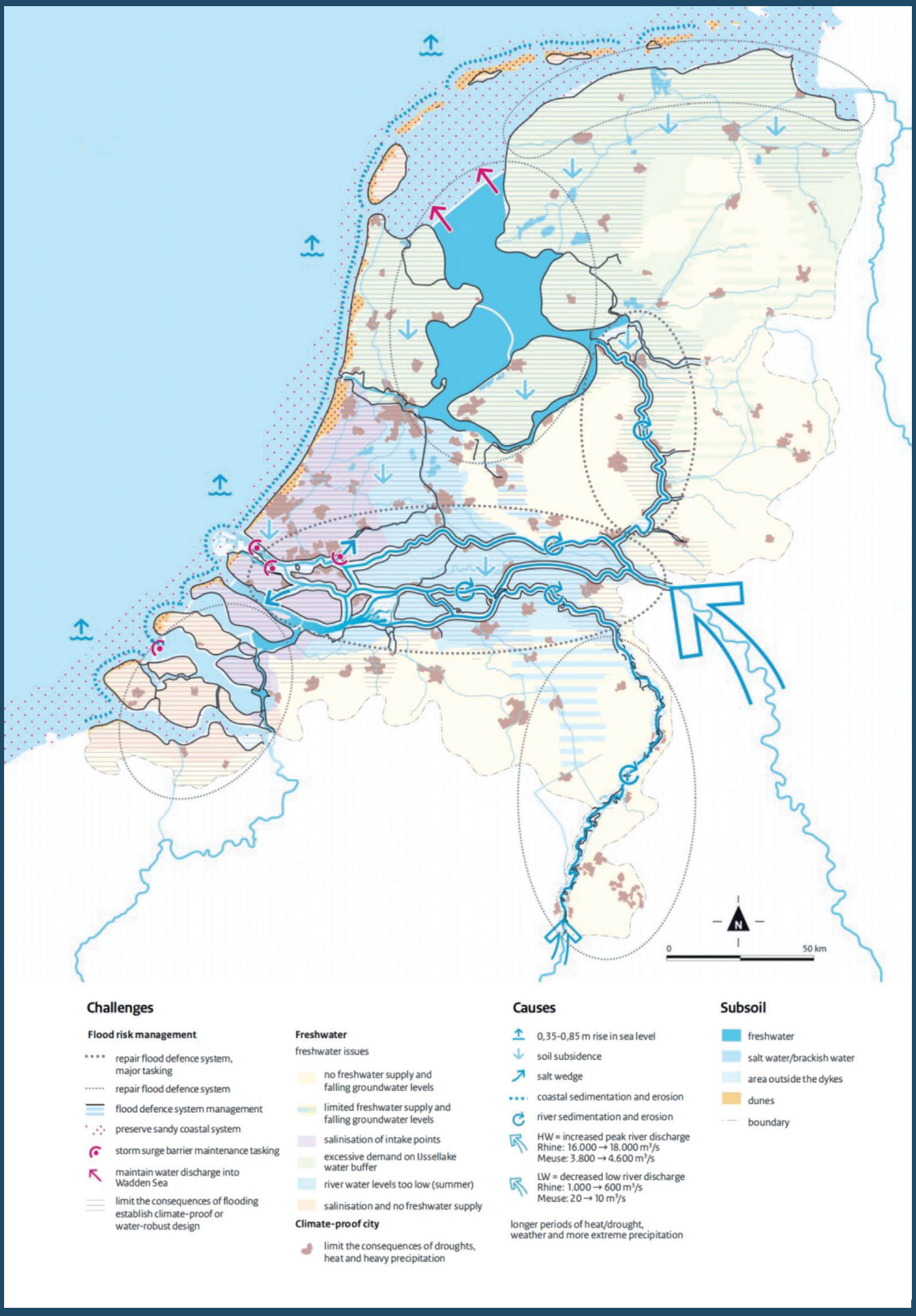

Figure 1: Flood risk management and freshwater challenges in the National Water Plan

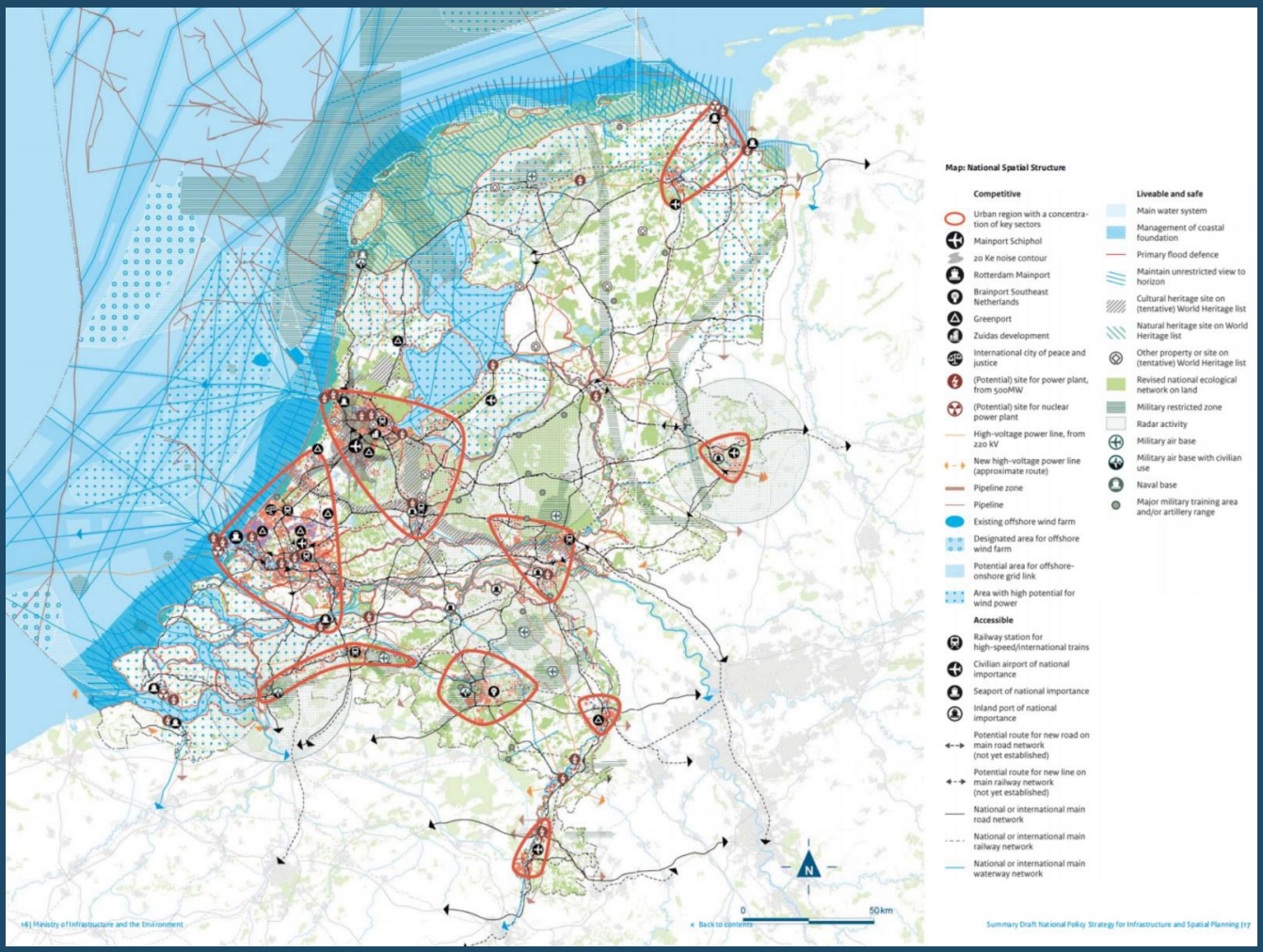

Figure 2: Schematic diagram of livability and safety in the Infrastructure and Spatial Structural Vision 2040

Table 10: Climate adaptation measures in the National Climate Adaptation Strategy

Highlight Measures	Descriptions
Creation of an online community for spatial adaptation data	An "online community" portal website will be created, integrating existing spatial adaptation knowledge portals, and ensuring that all departments can contribute and share relevant data. This includes relevant data on the physical environment, social sectors, and rural areas related to climate change adaptation. One of the key functions of this portal website is to provide data versions of charts in NAS and regularly update them, fully utilizing the possibility of user interaction, so that everyone can contribute to the entire process.
Cross-over Solutions	New alliances are formed to address potential 'intersections' (i.e. issues that require cross departmental coordination and resolution) and explore the intersection solutions in the following 9 cross departmental areas: Water-Nature-Urban Design-Health · Prevention of cyanobacteria and lower incidence of infectious diseases for better water quality · An attractive environment which invites outdoor recreational activity · More greenery to decrease heat stress. "Smart" design in the interests of air quality

Cross-over Solutions	Water-Spatial Planning-Public Spaces-Housing-Infrastructure · Urban transformation based on climate-proof design · New planning and environment legislation to promote cooperation and create cohesion · Tackling potential flooding within the spatial structure · Knowledge-sharing between local authorities and suppliers with a view to promoting climate adaptation · New design requirements for (residential) buildings and roads · Subsidence and water table management in relation to spatial functions Transport-Infrastructure-IT · The Ministry of Infrastructure and the Environment to approach the roads infrastructure with due regard for urbanization, sustainability, and climate adaptation · Mobility is increasingly dependent on IT, as in the case of autonomous vehicles. Industry-Energy-IT · Disruption of industrial production due to failure of IT or electricity supply caused by heat or other extreme weather conditions Spatial design-Disaster management · Ongoing consideration for the maintenance of essential functions in a disaster management situation Agriculture-Nature-Water-Infrastructure · Good land management for the creation of climate buffers, while well-maintained soil retains water for less CO2 emissions · Stable logistic to support the transport of feed, livestock and other agricultural products Agriculture-Health · New animal species the Netherlands as a potential threat to human health (zoonoses) · Heat stress in animal sheds Agriculture-International Food Systems · High temperatures throughout the supply chain to produce more waste, resulting in both financial and health implications Climate response -Business climate · Manageable climate risks so that the country remains attractive as an international business location
Solutions for dealing with heat stress events	· Municipal authorities must develop local heating plans that consider the status of vulnerable groups in the community. · Provincial governments, municipal governments, and private stakeholders must implement (spatial) measures to prevent urban heat islands. · The Ministry of Health, Welfare, and Sports will provide public information on the risks of UV exposure and provide recommendations on lifestyle choices to address the increased risk of cancer incidence
Solutions for important and fragile functions	· Resilient and dynamic natural areas that are part of an interconnected pan-European network will be created. · Nature needs to be integrated into cultural landscapes, using the "natural ecological corridor" as part of the proposed approach to synergistically manage the components of waterways, grasslands, and the "light green" national natural network. · Developing adaptable and flexible conservation goals for natural areas and specific species · Preventing peat oxidation to help mitigate climate change · Expanding agricultural natural management to include activities to support adaptation to climate change · Further study the feasibility of incorporating climate adaptation measures into the Common Agricultural Policy · To address the issue of "coastal squeezes" (loss of natural habitats such as mudflats and salt marshes), artificial sandbars are constructed along or behind the foreshore.

Establishment of a monitoring and evaluation index system	Indicator establishment: monitoring the progress of NAS follow-up activities, reduced climate risk with a set of performance indicators; Simultaneously assessing whether new risks have emerged, or whether known risks are developing faster than expected. Basic monitoring system: adjusted from existing methods, to enable central government, provincial authorities, local authorities, water management departments, and other stakeholders to monitor the progress of climate adaptation. Baseline measurement method: focusing on this aspect of work to form a reference point for evaluating the progress of adaptation work and regularly updating the risk analysis results.

Provincial level

'Adaptability' is incorporated into spatial planning by improving the resilience of spatial planning and addressing energy depletion on the provincial level in the Netherlands. It is explained by taking Groningen Province as an example. In the early stage of its spatial planning, Groningen Province first analysed the potentials of water resources, marine resources, and energy consumption in the region under long-term climate change impacts. Based on this, two kinds of interventions were designed to address these situations. The first approach is to draw a risk map of sea level rise and an energy development map, integrating multiple elements such as regional water resources, agriculture, energy, ecology, coastline, and urban development, and reflecting the mutual impacts amongst those elements. Based on the climate adaptation map of Groningen Province, land use was optimized and laid out to coordinate and support the overall spatial development, covering water storage areas, agricultural zones, coastal zones, living areas, etc. The illustration principles for each area are shown in Table 11. Based on the climate adaptation map, a resilience spatial strategy as the second approach for Groningen Province has been proposed [37,38], with the key elements shown in Table 12.

Local level

The concept of resilience has gradually influenced the allocation of land use, development functions, and building types, taking city of Rotterdam as an example, under the potential threat of climate change. Local level spatial planning understands resilience as enhancing the city's ability to maintain basic functions under impacts and disturbances, focusing on specific structural planning or more detailed land use planning. With a greater emphasis on implementation, and implementing resilience strategies at the micro level, Rotterdam's spatial planning focuses on infrastructure, vulnerable areas, and water issues, and has introduced a series of plans, such as the Rotterdam Climate Proof Program 2008, Rotterdam Adaptation Strategy 2013, Spatial Plan in Rotterdam Region 2020, Rotterdam Water Plan 2035, and Rotterdam City Vision 2030. Among them, the Rotterdam Climate Change Adaptation Strategy 2013 has proposed adaptation actions based on identifying urban climate risks [39,40], and the specific goals and measurements are shown in Table 13.

Table 11: The illustration principles of climate adaptation map in Groningen Province

Areas	Illustration Principles
Water storage areas	In the lowest parts of the province, water is stored. Even in dryer periods, water is kept in this lowest area and creates wet circumstances in a natural way. This enables nature to develop a robust ecological connection between the Dollard and Lauwers Lake. Existing brooks discharge their water from the higher grounds on the Drenthe plateau. In the ecological zone existing as well as colonising species can find suitable habitats.
Agricultural zones	The water storage areas also function as the water resource to provide agriculture with enough water of good quality. The water can be transported towards the agricultural ground by making use of the existing canal system in the Peat Colonies.
Coastal zones	The salinity along the northern coastal zone increases, due to the sea level rise and the increased salty seepage. This makes this area suitable for saline agriculture and aquacultures. Near Lauwers Lake, Dollard, and around Delfzijl space is created to inundate water from the sea into climate buffers. The combination of salt and sweet water makes it possible to generate energy in an osmosis plant.
Living areas	In front of the Northern Coast new Wadden Islands are created to protect the province, to develop nature and to provide development locations for living and recreation. The safest parts in the province to create living areas are found in higher elevated areas: Around Leek and the city of Groningen and in the southern part of the Peat Colonies and Westerwolde.

Table 12: The strategic interventions in Groningen Province

Object	Interventions
Fresh water storage in Lauwers Lake	Fresh water is stored in the Lauwers Lake by heightening the level of the water in the Lake. As a result of the risen water level the entire water system (the swarm) of Groningen is forced to adjust itself and keeps the high water level in the Reitdiep stream and other small canals and brooks. The capacity to store rainwater is increased by this simple intervention, which helps to deal with heavy rain showers and potential flooding in villages and towns.
Kwelderworks Eemsdike	Old-fashioned kwelderworks, natural processes, that fixate sand and mud, are re-introduced in front of the Groningen coast. These processes enable the soil to slowly grow along with the rising sea level until it finally rises above the sea level. When new arable land is needed it is possible to turn the area into agriculture, industrial areas or ecological space, when needed.
Blauwestad	The eastern part of the Province of Groningen has traditionally been the poorest region in the Netherlands with pervasively high unemployment, low levels of education and poverty. The Blauwestad area is one of the lowest places in the province and easily impacted by heavy rainfall. The introduction of a new luxurious village around a lake, the Blauwestad, has resulted in the upgrading of the entire area. Where economy is improved, the amount and quality of the infrastructure is improved, and unemployment is decreased.
Dynamic coast Fivelboezem	The coastline between Eems harbour and Delfzijl is the most vulnerable in the province. In the hinterland a dike supports almost every die piece in the province and a breakthrough may cause a flood that would reach the province capital within 24 hours. This strategic intervention consists of the perforation of the existing sea dike and the creation of a second dike in the hinterland. The area between the old and new dike will be flooded semipermanently. In this area dynamic circumstances emerge, both from an ecological point of view (brackish, changing water levels) and from a human perspective (living on newly built artificial hills, changes in wet and dry surroundings).

Table 13: Adaptation goals and actions in the Rotterdam Adaptation Strategy 2013

Risk	Targets	Measurements
Flood	Beyond the embankment: equal emphasis on prevention and adaptation. Inside the embankment: emphasis on Prevention	Rebuilding or maintaining storm surge barriers
		Developing adaptive building design specifications
		Robust infrastructure construction
		Strengthening risk management and enhancing risk awareness among residents and enterprises.
Extreme rainfall	Reducing urban vulnerability	Planting trees and permeable plants in open areas; using porous permeable paving stones.
		Construction of water squares and underground reservoirs.
		Green and blue roofs
Drought	Building a robust and resilient water system	Adding new climate buffer zones (i.e. lakes, canals, waterways, ditches, etc.)
		Increasing the number of plant communities; improving the water permeability of the road surface.
High temperature	Improving plant coverage in built-up areas	Improving green coverage (i.e. green roofs, green courtyards, blue corridors, etc.)
		Using of high reflective materials in public areas
		Water landscape design (i.e. fountain)
		Enhancing building insulation performance
		Enhancing citizens' awareness of high temperature risk.

3.2.3 Summary

Key perspectives on climate strategies in spatial planning in Netherlands, can be found as follows:

Firstly, climate strategies have given prominent reflections to the challenges faced by the country and highlighted local features. In the context of EU integration, spatial planning in the Netherlands not only emphasizes the need to strengthen the connection with space policies amongst EU countries, but also requires consideration of the spatial planning and layout design from the perspective of Europe as a whole, to achieve the goal of integrating into Europe while maintaining their own features of the Netherlands. With the pioneering experience of Netherlands in open space and green structure planning, as well as the unremitting efforts in water resource management and climate resilience improvement, a spatial planning system with unique national features has been formed, to solve merging problems faced by the country through targeted spatial planning.

Secondly, the visualization of climate related information has been emphasized, which is convenient for risk management, monitoring, and evaluation. In the spatial planning of the Netherlands, detailed labelling is provided for the layout of climate risk management facilities or systems, as well as the areas threatened by climate risks and the climate resilience issues. This enables the assessment of regional vulnerability and the vulnerability of important functionalities under extreme weather conditions, to implement climate risk management and targeted solutions.

Lastly, it is of great importance to effective inter-department collaboration. Whether to implement the "online community" and "crossover" solutions (See Fig. 10) at the national level, or the resilient spatial strategies at the local level, the spatial planning system in the Netherlands places great importance on cross-departmental coordination and data interconnection, and proposes targeted, comprehensive, and effective solutions to problems faced by the country or local areas.

3.3 Denmark

3.3.1 Implementation of Spatial Planning in Denmark

As a Nordic country, Denmark is featured with a small land area, high population density, and limited resources, however, it has accomplished a complete spatial planning. Since the first Planning Act (Planloven) was passed into law in 1992, Denmark has officially established a three-level planning system of "national - regional - local", with clear goals, content, and procedures of planning at all levels. Until 2014, due to the continuous simplification of regional administrative institutions and corresponding regional planning adjustments, the planning system was adjusted to national level and local level. In the development process of Denmark's spatial planning

system, the concept of green, low-carbon, sustainable and resilient development has been implemented, making Denmark recognized as one of the most successful countries in achieving green and low-carbon development in the world.

3.3.2 Strategies for Addressing Climate Change in Spatial Planning

National level

In 2008, the Danish Strategy for Adaptation to a Changing Climate was released, which identified the vulnerability of 11 key sectors in terms of climate change, including coastal management, buildings and infrastructure, water supply, energy supply, agriculture and forestry, fisheries, nature management, land use planning, health, rescue preparedness, insurance aspects, and outlined possible measures to enhance climate resilience[41,42]. The availability of climate change related data and information is crucial for the entire society to adapt autonomously and systematically to climate change. Therefore, the document proposes the introduction of a climate change portal website, which can access all information related to climate change and contains data information as shown in Table 14.

Local level

Taking the Finger Plan [43] of Copenhagen as a typical epresentative, the plan divides Copenhagen into four parts: the urban core area (palm), the surrounding urban area (fingers), the green wedge[2], and other areas.

Table 14: Climate change portal data proposed in Denmark Strategy for Adaptation to a Changing Climate

Data Categories	Specific Data
Climate data	Data related to temperature, precipitation, and wind speed, such as number of heat waves, duration of heat waves, length of growing season, evaporation, number of days with temperatures below freezing, largest quantity of precipitation over a given period, duration of droughts, extreme snowfall, highest wind speed, etc.
Groundwater data	Groundwater level, runoff data, etc.
Oceanographic data	Average sea levels, sea temperature, salt and oxygen content, surface current, storm surge heights, ice coverage, etc.
Geodata	Place names, buildings, roads, addresses, and areas registered in the Cadastre.

The Finger Plan clearly stipulates the definition, scope, and construction intensity of green wedges. As a key area that limits the disorderly expansion of urban development, green wedges are strictly prohibited from being converted into urban construction land or used for the development of urban entertainment facilities. Existing farmland, forest land, rivers, wasteland, and parks are strictly protected as green open spaces. Residential, commercial, and other urban facilities are not allowed to be built within the green wedge, and only a few villages are located within it. Only small-scale buildings and projects are allowed to be implemented in these villages to adapt to the local landscape and natural and cultural values. It is not allowed to install wind turbines, solar panels, and other equipment inside the green wedge to ensure that its entertainment value and landscape value are not affected. Agricultural landscapes are an essential part of the green wedge, but intensive livestock development requires evaluation before it can be carried out.

In response to extreme weather conditions, the Finger Plan proposes that for areas within the green wedge that have not been used as transportation corridors, facilities can be established to adapt to climate change while meeting landscape and functional needs as much as possible. For example, sunken basin areas and river channels can be used as recreational spaces during normal times and can serve as temporary rainwater storage systems in extreme weather conditions to increase regional rainwater infiltration and supplement groundwater resources. In addition, in view of the increasingly frequent rainstorm and flood disasters, Copenhagen has successively proposed the Copenhagen Climate Adaptation Plan [44] and the Cloudburst Management Plan [45] in 2011 and 2012, innovatively

2 The green wedges comprise radial wedges between the city fingers, the transverse wedges (green rings) and the wedges within the city fingers, including coastal wedges in the Helsingør and Køge finger.

proposed the "blue and green strategy", linking green space and water system, which are two spaces with climate change adaptability, and connecting with the traditional grey pipeline system. For example, the construction of sunken green space will play the role of sponge to absorb rainwater in rainstorm and share the flood discharge pressure of urban drainage system; roads that can transport surface water to lakes or bays are planned and set up; rainwater retention parks and streets are built, and rainstorm pipelines are reduced. These strategies can mitigate the impact of extreme rainstorm, improve the community environment and microclimate, and improve the quality of urban landscape.

3.3.3 Summary

From the perspective of climate change strategies in Danish spatial planning, there are several features:

The first is data disclosure. The Danish Climate Change Adaptation Strategy proposes the idea of integrating information from various departments and establishing a unified portal website. The availability of data and information is crucial for the implementation of climate change adaptation work by the means of integrating multiple data sources, including corresponding adaptation measures, establishing portal websites, and publicly publishing data. In addition, these data have a common geographical foundation, which means relevant data in the region can be accurately accessed based on positioning and can be effectively compared and used across geographical and administrative boundaries. It has positive significance for government decision-making departments to formulate policies, for research institutions to carry out mechanism or technological research, and for public knowledge popularization. Various levels of society can fully understand the impact of climate change on various aspects of social development, so as to adapt to climate change independently and in a planned manner.

The second is the openness of planning spatial layout. With the advancement of European integration, Denmark has gradually formed an open and diversified spatial planning pattern. The spatial planning at the regional level in Denmark is typical of the Finger Plan of Greater Copenhagen region, which is characterized by breaking traditional administrative boundaries, fully combining the terrain features of the region, forming a radiating urban framework, and assigning appropriate planning arrangements to specific areas [46]. The detailed division of functions in different regions makes spatial planning highly efficient. The radial transportation services and architectural layout not only strengthen the central urban area, but also help promote public transportation and green travel, reduce greenhouse gas emissions from transportation, and have a positive effect on climate change mitigation and environmental quality improvement in the region; The green open spaces distributed between urban areas have also been effectively protected and utilized. The approach of concentrating future urban development around rail transit stations will effectively address the integration of public transportation and urban development [47], which has good reference value for other countries intending to solve urban transportation carbon emissions problems through regional planning.

3.4 Sweden

3.4.1 Implementation of Spatial Planning in Sweden

Sweden established the Planning and Building (Plan-och bygglag) Act [48] in 1987, which clarifies that at the national level, only concepts, principles, and construction goals are defined. According to this act, no national level plans are established but specific plans are prepared and implemented locally. Further, the Planning and Building Act stipulates that local governments should prepare a structure plan covering the entire city as an overview strategic document to serve as a strategic and guiding document while clarifying the long-term development direction of the local physical environment and the importance of climate change issues for sustainable development in the city.

3.4.2 Strategies for Addressing Climate Change in Spatial Planning

As the first city to be selected as the "European Green Capital", Stockholm, the capital of Sweden, is recognized as one of the cleanest cities in the world. It has shown long-term attention to green space, ecological protection, energy conservation and emission reduction, and sustainable development, and its planning system is also at the forefront of the world. The Planning and Building Act at national level requires cities to develop comprehensive planning, which has become an important legal basis in the field of urban planning in Stockholm [49].

In 2006, Stockholm launched the Stockholm Park Plan, which required 90% of residential buildings in the city to achieve park green spaces within 300 meters, and formulated policy measures to promote urban biodiversity, improve urban environmental quality, and promote the development of the service industry. A park system consisting of internal parks, ecological corridors between new cities, peripheral suburban parks, and nature reserves has been formed, accounting for 40% of the urban area. It is the largest bioenergy with

carbon capture and storage (BECCS) system in the city. Stockholm's attention to the park system reflects the city's ability to apply natural background, emphasizing the maximum utilization of existing natural resources, optimizing the urban environment, improving citizens' sense of happiness in life, and achieving the improvement of urban resilience while protecting resources.

In 2010, Stockholm formulated a new urban plan called the Walkable City - Stockholm City Plan [50], repeatedly mentioning sustainable development goals and requiring that the establishment of transportation systems be fully constrained by environmental protection technologies and emission reduction goals. This was an incredibly challenging and forward-looking strategy in 2010. The Stockholm City Plan identifies 10 key areas, including those related to climate change and their planning strategies, as shown in Table 15. Besides, Stockholm has built a bicycle network to make citizens' travel greener. Currently, the city's bicycle lanes have exceeded 760 kilometres, and each transportation node is equipped with a dedicated bicycle storage area. The city also has 9 official bicycle pumping points, continuously improving the convenience of cycling, which reflects the city's emphasis on green and low-carbon transportation and is committed to building a green slow moving transportation system in all aspects based on the city's features, in order to solve the carbon emissions problem in the transportation field.

Also in 2010, the Regional Development Plan (RUFS 2010) [51] was introduced, identifying the key changes and risks brought by climate change to the Stockholm region, and proposing future planning strategies from both mitigation and adaptation aspects, as shown in Table 16. In addition, a separate compilation of environmental assessments has been developed, which includes an assessment of the impact of the environmental quality goal of "climate change mitigation" on areas such as transportation, energy supply and consumption, public health, environmental risks, water environment and resources, urban assets, regional green structures, islands, and rural areas.

Table 15: Key areas and planning strategies related to climate change in the Stockholm City Plan

Key Areas related to Climate Change	Planning Strategies
Water resources and coastal zone management	When implementing water body plans, it is necessary to consider the impact on the entire catchment area of lakes and waterways. When planning residential, transportation infrastructure, or other land uses, a stormwater strategy should be adopted.
Green space construction	· Improving the park programme and prioritizing improving the safety of parks and green spaces. · Protecting and improving urban ecological infrastructure in the form of core areas, transition zones, and buffer zones, protecting ecologically sensitive watersheds and water bodies, and enhancing the adaptability of vulnerable areas through the construction of coastal corridors along ecologically sensitive coastlines.
Transportation system and sustainable transportation	· Using financial tools to influence transportation and travel patterns, such as implementing congestion taxes and parking policies to encourage public transportation and evaluating the impact of different financial tools on accessibility. · Establishing dedicated bus rapid transit lanes to minimize administrative barriers in public transportation. · Establishing a safe bicycle road network and improve parking infrastructure. · Improving the design of the street environment to provide good travel conditions for pedestrians and cyclists.

New energy and public infrastructure	· Providing small-scale solutions to replace traditional energy sources such as solar panels, wind energy, and geothermal energy in existing and new housing development projects. · Promoting energy-saving buildings through urban planning and building permit approval. · Setting up convenient household waste collection points for residents, vacuum management systems for household waste, and underground waste collection stations.
Health, Safety, and Environment in densely populated cities	· When planning for climate disasters such as floods or landslides, the adaptability of buildings and infrastructure to risks should be considered. · Rainwater should be discharged through porous surfaces as much as possible and treated on-site. · Vegetation plays a crucial role in mitigating climate change and stabilizing urban coasts. · When positioning and designing new development projects, risk sources should be clearly identified, defined, and evaluated, and whether further background data is needed to support the planning process should be reviewed.

Table 16: Key areas and planning strategies related to climate change in the Regional Development Plan

Fields	Planning Strategies
Infrastructure investment	For areas susceptible to climate change such as buildings, highways, railways, power, and telecommunications networks, as well as water supply and sewage treatment systems, it is necessary to assess their risks, vulnerabilities, adaptability, and resilience levels, and establish risk mitigation and support systems.
Flood risk control	· Landslide and flood risks, as well as sea level rise, must be considered in urban planning. · The height of the flood embankment should be raised.
Transportation	Promoting a high proportion of biofuels, plug-in hybrid vehicles, and other environmentally friendly vehicles, promoting public transportation, formulating environmentally friendly parking policies, and investing in intelligent transportation systems and services
Construction and service industry	· Developing district heating based on biofuels. · Renewing low energy passive residential building standards. · Establishing independent and decentralized energy self-production and self-use high-level buildings in areas with low population density. · Carrying out new energy services for climate intelligent buildings.

The Stockholm Environment Programme 2012-2015[52] was introduced in 2012. This programme was developed within the framework of the Stockholm Vision 2030 - A Guide to the Future [53]. This document considers the primary environmental issues of cities from 6 aspects: transportation, chemicals, energy, land and water, garbage, and indoor environment. 6 major goals and specific action plans and indicators are proposed accordingly. Table 17 shows the indicators related to climate change mitigation and adaptation.

Table 17: Indicators related to climate change in the Stockholm Environmental Programme 2012-2015

Aspects	Targets	Index
Environmentally efficient transport	The city' s own vehicles will be environmentally certified and powered by alternative fuels, and the proportion of green vehicles in the transport services procured by the city will be increased.	The proportion of environmental vehicles in the city' s vehicle fleet
		Proportion of alternative fuel in the city' s green cars
		Green-car proportion of City vehicle purchases
		Proportion of the City' s procured transports that are environmentally certified
	Pedestrian and bicycle travel shall be increased.	Number of bicycle passages
		Proportion of Stockholmers who walk or bike to work
		Number of kilometres biking distance
	The proportion of public transport will be increased.	The proportion of journeys by public transport
		Proportion of public transport users
	At least 50% of new private cars should be green cars. 10% of all new registrations of heavy trucks should be environmentally certified. Sales of renewable fuels should amount to 16% of total fuel sales.	Proportion of new car sales in Stockholm County that are green cars
		Renewable fuels as a proportion of total amount of fuel in Stockholm County
		Number of green cars in Stockholm traffic
		Proportion of petrol stations offering renewable fuels
		Proportion of green cars that pass across the congestion tax cordon
Sustainable energy use	The city will through energy efficiency measures reduce energy use in its own operations by at least 10%.	Energy use per m^2/year in the city' s committees and boards
	Procured electricity in the city' s own operations should meet the demands for environmental certification.	Electricity use per m^2/year in the city' s committees and boards
		Amount of green electricity
	Regarding land designation, the city should demand that energy use be a maximum of 55 kWh/m2.	Proportion of newly built houses that live up to the demand for energy use to be no higher than 55 kWh/m^2
	The city will strive to reduce the emission of greenhouse gases to a level no higher than 3.0 tonnes of CO2e per Stockholmer.	Emissions of greenhouse gases (CO_2e) per Stockholmer
		Emissions of greenhouse gases from traffic
Sustainable use of land and water	Land and water areas of particular importance for biodiversity will be protected and developed.	Utilised surface of particular importance for biodiversity
		Number of naturally occurring bird species in built-up environments
		The number of naturally occurring species – for example vascular plants, birds, butterflies
		Proportion protected natural land of total area
	Intrusion into other green and water areas should be minimized and compensated for.	The proportion of projects that claim land with ecological and recreative values that are green compensated
		Proportion of projects that claim land with ecological values that are compensated with other ecological values
	When changes are made to land and water areas, these will be shaped with future climate change in mind.	Proportion of permeable surface
		Proportion of area with canopy cover
		Proportion of detail plans where consideration has been paid to climate changes
	Water quality in lakes and waterways will be improved..	Total level of phosphorus in lakes
		Visibility depth in lakes
		Proportion heavily trafficked road surface with runoff
		Overflow of wastewater

3.4.3 Summary

Due to Sweden's lack of national level spatial planning according to the Planning and Building Act, specific plans are formulated and implemented locally. Therefore, this study mainly summarizes them at the local level. Taking Stockholm as an example, the strategies for addressing climate change in urban spatial planning have the following features:

The first is to attach importance to the application of regional natural environmental background, emphasizing the integration and development of cities and nature. In the construction of urban park systems, emphasis is placed on the naturalness of the urban structure, preserving the natural landscape as much as possible, and maintaining the natural pattern of the city. In addition to the ecological corridors in the suburbs, Stockholm also infiltrates natural space into the city through the establishment of a layered park system, forming a unique form of green space system in the city, which not only meets the demand for high-quality ecological environment in modern cities, but also protects the natural resources within the city and enhances its climate resilience.

The second is to form distinctive carbon reduction strategies through the construction of large-scale green and low-carbon transportation networks. Transportation is one of the main sources of greenhouse gas emissions in the city, therefore the development of new energy vehicles and the construction of green and low-carbon transportation systems have become the main means for countries around the world to achieve low-carbon urban transportation. But for Stockholm, the uniqueness of its green and low-carbon transportation network lies in its scale. Whether the widespread layout of bus lanes, pedestrian networks, and cycling networks throughout the city, or the reduction of service infrastructure and strict tax policies for small cars, it can form a transportation mode dominated by public transportation throughout the city, and truly create convenient conditions for green travel, which is a planning strategy with strong carbon reduction goals.

Efficient and Comprehensive Transport Network in Gothenburg, Sweden

4. Recommendations and Suggestions

Integrating climate strategies into spatial planning is to reduce greenhouse gas emissions, increase carbon sinks, reduce the vulnerability of infrastructure, ecological environment, and economic society through spatial layout and regulatory implementation. It enhances the climate resilience of national space at the macro level and human comfort to the climate and environment at the micro level. Spatialization is an effective way to systematically maximize the effectiveness of climate actions [54]. By summarizing the practical experience of country case studies, the following suggestions can be drawn:

Firstly, there should be a phased focus on addressing climate change in spatial planning. Since spatial planning is a long-term and comprehensive development plan, it requires a planned and step-by-step approach. Similarly, addressing climate change is also a long-term and comprehensive issue. Therefore, strategies for addressing climate change in spatial planning should reflect the features of the development stage. For example, the inclusion of "addressing climate change and shaping the energy revolution" in the concepts and actions of German spatial planning is a positive response to the global development situation. It is recommended to adjust the spatial planning objectives in different development periods and stages, as the development background and socio-economic goals change. At the same time, strategies to address climate change, which are closely related to space policies, should also be adjusted simultaneously, along with a timely adjustment mechanism.

Secondly, each level of planning should have a clear focus of the mandates and to be interconnected with each other. The spatial planning systems of the EU member states mentioned above have detailed hierarchical divisions. It is necessary to clearly define each level of planning from the aspects of the positioning, the role, the content, and the preparation procedures, etc., to avoid any overlapping or contradictions. What China and other countries can learn from this is to clarify the roles of planning at all levels, and effectively connect the various levels. For example, at the national level, emphasis can be placed on overall and strategic aspects, key controlling elements, the main mitigation and adaptation tasks, key influencing factors and the coordination amongst core regions. The regional level serves as a connection layer between the superior and subordinate planning levels, playing a coordinating role in identifying key issues in responding to climate change, carrying on specific tasks at the national level, and conducting overall planning from a regional perspective. At the local level, it is necessary to undertake the guidance of national and regional low-carbon and resilient spatial patterns. It is also crucial for the local level to implement spatial control and construction management in accordance with the principles and requirements proposed in the superior planning. design mitigation and adaptation strategies that conform to local features, strengthen indicator control, and address mitigation and adaptation issues in a targeted manner.

Thirdly, it is to sort out the network with relevant departments to achieve collaboration and coordination amongst key departments working in the intersection of climate change and spatial planning. The effective implementation of climate strategies in spatial planning depends on the effective connection with related departments. As a comprehensive management platform, spatial planning needs to establish a clear guiding framework, especially on the interlink of key tasks addressing climate change issues. It is therefore suggested to sort out key tasks of addressing climate change and the involved departmental relationship and network. The "Cross-over Solution" proposed in the adaptation strategy of the Netherlands, shows advantages in clarifying the roles and responsibilities of relevant departments for each key task and the expected goals, and facilitating data coordination and information exchange in different fields.

Finally, it is to strengthen the application of nature-based solutions and emphasize the openness of spatial layout. In Swedish planning, the infiltration of urban environment into the natural environment not only maximizes the protection of natural resources, but also utilizes nature-based solutions to solve urban problems, maximizing the adaptation to local condition and efficiency on resource utilization. In this process, it is suggested to break administrative boundaries in the setting of key strategies, fully integrate the terrain features, and highlight the openness of spatial layout. Like the Finger Plan of Copenhagen, Denmark, urban climate resilience can be effectively improved through the unified application and management of space elements, including the space forms, transportation network, infrastructure, green structure, rivers, and lakes, etc.

Transportation in a Historic European City Center

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