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Report on Global Environment Competitiveness (2013)

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Abstract

Since the 1970s, environmental issues have gradually transcended national boundaries, and evolved into regional and global issues from local issues, also caused great concern in the international community. Especially in recent years, in the face of the global financial crisis, countries around the world view the green transformation of economic development as a breakthrough point, and actively participate in and promote international negotiations on environmental issues and global cooperation to ensure the sustainable development of economy, society, and environment for our planet and future generations.

Global environmental competitiveness is a whole new way to measure the competitiveness in the context of the contradiction between world economic development and environmental protection has become increasingly intensified. Global environment competitiveness covers the ecological environment, resources environment, environmental management, environmental impacts and environmental coordination five aspects, highlighting the environment as a basic element of human production and life, paying attention to the coordinated development between human and the environment. At the same time, it also gives full consideration to the economic system and social system's impact on the environment, comprehensively reflecting and embodying a country's development ability of environment through a variety of means such as economy and administrative. In a word, global environment competitiveness is an important content to measure the competitiveness of a country.

This book uses longitudinal study and horizontal analysis, combining qualitative and quantitative analysis methods, so as to conduct in-depth study of theoretical, empirical and methodological issues of the global environmental competitiveness. This book is shape of three main parts. The first part is divided into the theory and method, which expounds comprehensively the important significance, the main content and the technical route of global environmental competitiveness research, and then according to the characteristics of global environmental competitiveness it establishes the global environmental competitiveness evaluation index system and the mathematics model, forming a relatively comprehensive global environmental competitiveness analysis framework. The second part is the total report which selects the global 133 representative countries as evaluation objects, analyzing the development status of global environmental competitiveness as a whole, revealing the strengths and weakness of each country’s environmental competitiveness and providing the basic paths and strategies of enhancing the competitiveness level. It will provide valuable analysis basis and policy reference for all countries in the world to realize sustainable development. The third part is sub-report, which evaluates environmental competitiveness respectively for 133 countries around the world, revealing the characteristics and relative differences of environmental competitiveness of different development types and levels countries around the world, in order to provide important decision-making reference for making environmental economic policies,
accelerating the green economic transformation and enhancing the environmental competitiveness.

**Preface**

Environment is the foundation and support of human existence and survival and the guarantee of sustainable human development; environmental protection has undoubtedly become a common understanding and development strategy of all countries of the world. The influence of environment on economic and social development has never been so obvious and people's understanding on environmental issues has neither been as profound as it is today. In particular, with the heavy attack by global financial crisis and the progress of industrialization, people begin to seek rebalancing between humankind and environment at a higher stage of development. In the world today under the tide of economic globalization full of challenge and competition, the focus of competition is no longer only limited in the economic, political and military fields; competition in the environmental field has also attracted wide attention from all over the world. Environmental management and climate change resilience have been recognized by all countries and regions as important leverage in participation in international competition. So to speak, environmental competitiveness has become a key component of the comprehensive competitiveness of a nation or region.

Researches on environment competitiveness and environmental issues are in the same line. The results of researches on environmental issues over the past hundreds of years have provided precondition and foundation for the research on environmental competitiveness, while environmental competitiveness researches integrates both environment and competitiveness, breaking the limitation of studies on environmental issues alone and making in-depth discussions on environmental competitiveness from multiple disciplines of economics, management science, operation research and sociology; it emphasizes exploration into environmental ability and leads to new economic model, development pattern and life style. In summary, doing environmental competitiveness research not only further deepens and advances the theories about environment and competitiveness, but also fits into the trends of global environmental protection, and thus having important theoretical and practical significance.

At present, environmental impact has gone beyond the regional and national scope, changed from a local issue to a regional and global issue. Due to the pervasion and uncontrollability of environmental damage and pollution, the environmental pollution or safety accident in one country or region might very often endanger the surrounding countries and regions or even cause global environmental disaster. Therefore, to enhance global environment competitiveness requires all countries to consider the issue from the basis of common benefit of the globe, strengthen dialogue and negotiation, jointly combat and solve global environmental challenges and promote the coordinated advancement of global environment competitiveness. In the meanwhile, after experiencing the hit of global financial crisis and the debt crisis in the euro zone,
global economy has also come to a stage of bumpy speeding down for transformation. This has set an urgent need to break the bondage on traditional development pattern, change the mode of relying on high input in return for high output, seek the engine to lead the new round of economic growth, focus on synchronized economic growth, social progress and environmental improvement, enhance all countries' ability to face with environmental problems and crisis and strengthen international environmental protection agreement execution and collaboration, so as to enhance global environment competitiveness and realize the happy vision of global sustainable development.

Environmental issue is a global issue. Governments of all countries of the world must have the wisdom and courage to go beyond the bondage of narrow national interest; walk towards the directions of international cooperation, collective security, common benefit and rational negotiation that are pursued by humankind; adopt effective environmental measures; jointly build a continuously progressing world, a low-carbon and harmonious world; apparently enhance global environment competitiveness; and realize global sustainable development. Therefore, the Fujian Normal University Branch Center of National Research Center of Comprehensive Economic Competitiveness initiated the research on the first green book Report on Global Environment Competitiveness (2013), with the strong support and help of United Nations Environment Programme (UNEP) senior economist Sheng Fulai. During 25-26 March in 2013, United Nations Environment Programme, Chinese Academy for Environmental Planning of Ministry of Environmental Protection of China, Policy Research Center for Environment and Economy of Ministry of Environmental Protection of China and Fujian Normal University jointly organized the "International Workshop on Green Economic Transformation and Environmental Competitiveness indicators" in Fuzhou City, China. More than 40 well-known experts in the field of environmental economics, from the UNEP, World Economic Forum, World Wide Fund For Nature, Global Green Alliance, Institute for International Environmental Strategies, International Labour Organization, Indonesian Ministry of Environment, Ministry of Finance of Uruguay, Commission on Sustainable of Mauritius, Institute for Green of Korea, Central European University, University of Malta, Ministry of Environmental Protection of China, Chinese Academy of Sciences, Chinese Academy of Social Sciences, China Center for International Economic Exchanges and Beijing Normal University, attended the workshop and deeply discussed the discussion paper "Global Environment Competitiveness Indicator System and Evaluation". The experts believe that "Report on Global Environment Competitiveness" is the first report on global competitiveness evaluation led and introduced by the developing country, and it is an important breakthrough and innovation. In order to further deepen the study of this project, after the workshop, the research group organized the research again for more than four months. We fully absorbed the valuable comments and suggestions proposed by experts and strived to make the research ideas, research methods and so on of the book effectively converge with the international rules. Before we finally show the study in front of the readers on schedule, we must express our sincere gratitude to the experts listed in below table.
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Since 2008, the research group embarked on the study of Global Environment Competitiveness and got the guidance and help of leaders and experts of Chinese Academy for Environmental Planning. We released 2 green books, i.e. Report on China's Provincial Environment Competitiveness Development (2005-2009) and Report on China's Provincial Environment Competitiveness Development (2009-2010). The former won the first prize of Fujian Excellent Social Science Achievement Award and the second prize of the sixth Universities Excellent Achievement Award (Humanities and Social Sciences) Award. In the meanwhile, the research group also studied the China's Provincial Economic Comprehensive Competitiveness and National Innovation Competitiveness. During the NPC & CPPPPCC period in the years from 2007 through 2013, we successively released 7 blue books of Report on Overall Competitiveness of China's Provincial Economy, the yellow books of Report on Group of Twenty (G20) National Innovation Competitiveness Development.
(2001-2010), Report on Group of Twenty (G20) National Innovation Competitiveness Development (2011-2013) and Report on World Innovation Competitiveness Development (2001-2012) jointly with the Science and Technology Section of Chinese Mission to the UN; part of the research was also published in the English version in Paths of UK to the globe. The release of this series immediately attracted wide attention from government authorities at both central and local levels as well as the academic and theory circles and aroused wild reporting about the research in mass media in China and other countries, producing big social impact. It is worth mentioning that the blue book series of Report on Overall Competitiveness of China's Provincial Economy won the "Biggest Impact Award of the 1st China's Excellent Book Series Award" and "China's Excellent Book Series Award" and that the book series is the only research result presented by a local university among the 10 award winners. Another two reports prepared by the Branch Center, "General Evaluation Report on the Overall Competitiveness of Provincial Economies of China 2009-2010 " and "Overall Evaluation and Comparative Analysis of G20 National Innovation Competitiveness 2001-2010", again both won the first prize of the 3rd "China's Excellent Book Series Award-Report Award"; the Branch Center is also the only research group throughout the nation that won two first prizes in the award.

This first edition of the green book of Report on Global Environment Competitiveness (2013) is the latest research result of FNU Branch Center. We hope that, through furthering the research on global environment competitiveness, environmental economy will carry new connotations and we will make in-depth discussions about the development and future of GEC from theoretical, methodological and empirical dimensions so as to make our contribution to promote global sustainable development. Based on adequate reference to the previous results of related researches both in China and abroad, this study kept tight tracking on the leading research edge of multiple disciplines covering environmental science, economics, ecology, management, statistics, econometrics and human geography, analyzed the level, features of change as well as trends and driving force of environment competitiveness of world countries and established global environment competitiveness indicator system and mathematical model. We also collected the latest released the data of environmental economy of 133 countries of the globe; after scientific evaluation and comparative analysis on the processed data, the study finally revealed the features and differences of environment competitiveness of the countries of different type and at different stage of development, defined the environmental competitive advantage and weak links of each country and did follow-up study on the evolution track and path of enhancement of environment competitiveness; it will provide valuable theoretical guidance and practical measures for all countries to enhance environment competitiveness. The whole book is composed of three parts and annex; its framework is as follows:

Part 1 is Theory and Methodology, which makes clear the research contents and methodology used in the study. This part fully explains the significance, contents and evaluation methodology used in GEC research and establishes the evaluation indicator system and mathematical model of global environment
competitiveness according to the characteristics; the technical roadmap and analytical approach of this study are also introduced in this part, hence forming a complete analytical framework for global environment competitiveness.

Part 2 is General Report, i.e. general evaluation report on global environment competitiveness. General report evaluates and analyzes the environmental competitiveness of 133 nations in 2012 using the evaluation system composed of 1 index, 5 sub-indexes, 14 pillars and 60 individual indicators. Based on comprehensive analysis, the report makes in-depth analysis on the trends of GEC, introduces the regional distribution of environment competitiveness of the countries, reveals the environmental advantages/disadvantages and relative position all the countries and regions, summarizes the characteristics of GEC during the evaluation period and presents the elementary path and policy advice to enhance GEC, thus providing valuable decision-making reference for all countries in establishing environment development strategy.

Part 3 is Sub Reports, i.e. evaluation and analysis on environment competitiveness by country. This part is special reports that give comparative analysis and evaluation on the environment competitiveness of 133 countries covered by this study in 2012. It shows the characteristics and relative differences of environment competitiveness of the countries of different types and at different stages of development, defines respective competitive advantages and weaknesses and makes follow-up studies on the evaluation track and way of enhancement of environment competitiveness in each country.

Annexes list the evaluation scores of environment competitiveness and 5 sub-indexes in the 133 countries in the evaluation period, which will be good reference for readers who want to do quantitative analysis.

This book refers to an area of research crossing multiple disciplines and also a study of international issues involving 133 countries. Due to the constraints of both subjective and objective factors, such as knowledge structure and academic ability of the team and data availability, the research is far from thorough and complete in certain aspects and there are still many subjects requiring further study. We wish to join the intellectuals from governmental agencies, international organizations, academic institutions and universities of the world and environmentalists who have interest in global environmental issues to continue the research on GEC, thus making the evaluation objective and providing valuable decision-making reference for the sustainable development of economy and society in all countries.

Writers

August, 2013
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Environment is the foundation and support of human existence and survival and the guarantee of sustainable human development; environmental protection has undoubtedly become a common understanding and development strategy of all countries of the world. Now humankind is striving into the historical process of postindustrial society and is trying to reach rebalance with environment in later stage of development. All countries need to perform respective duties and obligations in environment governance, in joint efforts to plan economic development, social progresses and environment protection to realize mutual wins and sustainable development of the world and to create an Earth homeland for harmonious co-existence of humankind and environment.

Chapter 1 Theoretical and Reality Basis of GEC Research

Looking at environment, economy and social development, to promote sustainable development through global partnership must enhance environmental competitiveness to solve the global ecological environmental crisis. This is not only the premise and foundation to establish the argument of this research, but also where essential value and significance of this research lie in. Whether the sustainable development of human beings needs to enhance environmental competitiveness is an issue related to economic development, environmental protection and government function, and requires profound analysis and argumentation.

1.1 Theoretical Basis of GEC

Global Environment Competitiveness (GEC) is a comprehensive across-discipline research subject involving sustainable development economics, natural resource and environmental economics, environmentology, competitiveness theories and econometrics. Among these, the theories of such disciplines as natural resource and environmental economics, sustainable development economics, environmentology and competitiveness economics are the theoretical basis of environmental competitiveness research, while competitiveness evaluation methodology, econometric analytical approach and related analysis method in environmental economics also provide methodology reference.

1.1.1 GEC is a key component of environmental economic system

Ever since industrialization, especially after the 1950s, science and technology have made fast progress and humankind's ability to conquer the nature were also enhanced enormously. The industrialized civilization has brought about great material wealth as well as problems like deterioration of ecological
environment and resource depletion. The problems are now rather severe, but the mechanism of interaction in natural environment is so intricate that the future is full of uncertainty as for how natural environment change, and so far human beings know few about it, or even know nothing. The austerity, complexity and uncertainty in environmental problems have made the research on GEC more important in the environmental economic system.

Economy and environment are mutually influential and interactive, constituting an interdependent economy-environment system. First, in the economy-environment system (See Figure 2-1), economy and environment influence each other, with natural environment providing various natural resources (such as oil, mineral products and water) and different types of services (such as life support service and comfortableness service) for human economic system and at the same time economic system also influencing natural environmental system; natural resources entering economic system will eventually become byproduct or residue and return to the natural world. Secondly, economy and environment are mutually conditional; without the resources and services provided by natural environment, human beings can't survive or develop and human economic system can't operate well; meanwhile, if humans take too much from and discharge too much residue into nature as beyond the affordability of natural environment, then natural environment system will be damaged.

![Economy-Environment System Model](image)

**Figure 1-1** Economy-Environment System Model: Interdependence between Economic Activity and Nature

If human beings can correctly manage their behavior according to the laws of development in natural
environment, rationally utilize natural resources, harmoniously co-exist and friendly develop with ecological environment and continue enhancing global environmental competitiveness, then natural environment can provide not only good life support, comfortableness services, but also various natural resources, and help with the sustainable development of human economic society to realize the maximization of human wellbeing. Otherwise natural environment quality would be damaged, polluted environment quality would directly cause big loss in health, life, production, public facility, construction and property; and any preventive or compensative expenditure for such loss has an opportunity cost, which would reduce economic development. It is to say, natural environment shouldn't be regarded as an issue that has nothing to do with economics, but the core of economics and economic decision; global environmental competitiveness should be an important component of the comprehensive competitiveness of all regions of the world.

1.1.2 **GEC supplemented and developed environmental economic theories.**

The theoretical basis for the existence and development of global environment competitiveness are manifested in the theories of sustainable development economics, natural resource and environmental economics, environmentology, competitiveness economics and econometrics. It should be particularly noted that environmental economic theories are completely applicable to the research on environmental competitiveness; they constitute the theoretical basis of the intentional logic of environmental competitiveness. Sustainable development economics says that regional sustainable development system can be summarized into society, ecological environment and economy such three subsystems.

![Dynamic Forming & Acting Mechanism of Environmental Competitiveness](image)

**Figure 1-2 Dynamic Forming & Acting Mechanism of Environmental Competitiveness**

Ecological environment can provide production means for human society as well as life support and comfortableness services, which is the efficacy and benefit from ecological environment. Human beings will respond to the changes in such efficacy and benefit by improving social system and regulating social
behavior and thus influence the pattern, speed and scale status of economic development; different status will impose different pressure on ecological environment and ultimately leads to different development in the latter. What the different status of ecological environment will provide is also different efficacy and benefit, and human beings will in turn adjust their behavior according to the changes in such efficacy and benefit. In a word, regional sustainable development system is a combination of three synthetically interlinking subsystems of ecological environment, economy and society. This system is an integrated system under cyclic motion and dynamic development. Thus, the interaction process between ecological environment and its efficacy and benefit is very much similar to the mechanism between force and action in physics: the dynamic system of ecological environment under cyclic change and composed of social response, economic development pressure and changes in ecological environment eventually forms a environmental force, which acts on human society and realizes its efficacy and benefits for human beings. And, the result of action by the force will be fed back to the dynamic system of ecological environment cyclic change and forms again another new environmental force that acts on human society. Environmental force and its efficacy and benefit for humans are a dynamic developing process with cyclic change. Comparison of the environmental force in different regions will show the environmental competitiveness in these regions. We see, therefore, the relationship between environmental force and environmental competitiveness is like the relationship between absolute value and relative value; thus the dynamic mechanism of formation for environmental force—the dynamic system of ecological environment cyclic change, is also the dynamic mechanism of formation for environmental competitiveness (See Figure 2-2). To sum up, the theories of sustainable development economics is the basis for establishment of the concept of environmental competitiveness. Besides, other environmental economic theories also become the theoretical basis of the operation mechanism of environmental competitiveness. First, natural resources and environment allocation theories argue that environmental resource services do not have a market for trading due to their nature of externality and publicity or other causes, or the so called market failure; together with the other two even more ultimate causes of incomplete property right system and government failure, environmental problems like environmental resource abuse, exhaustion and pollution have thus occurred. Therefore, to solve these problems requires government sector to correctly understand the publicity nature of environment, correctly assess the value of environmental resource, establish necessary system to promote internalization of external influence and implement correct policy to regulate people's behavior, so as to realize coordinated development of economy and environment. This is an analysis of how social system influences economic behavior and further influences the status of ecological environment, or the analysis of the social response mechanism for dynamic formation of environmental competitiveness. Secondly, the econometric theories

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about environmental resource analyze the relationship between economic development and ecological environment from empirical angle. Environmentological theories and environmental status assessment theories are the basis of analysis on the development and changes in ecological environment status. Finally, environmental value theories and environmental accounting theories analyze and estimate the efficacy and benefit of ecological environment from micro and macro levels respectively.

Environmental competitiveness theory greatly enriches and develops environmental economic theories. First, environmental competitiveness comprehensively evaluates the dynamic development of ecological environment. Natural resources and environment allocation theory emphasizes particularly the analysis of how resource allocation system acts on ecological environment, the econometric analytical theory of environmental resource emphasizes analysis on the relationship between economic development and ecological environment from empirical angle, and environmentological theory and environment status assessment theory emphasizes the assessment of the status ecological environment; these theories almost all focus on certain angle in analyzing the dynamic system of cyclic change in ecological environment, but environmental competitiveness integrates three subsystems of social response, economic development pressure and change in ecological environmental status, which constitute a thorough evaluation of the dynamic development of ecological environment. Secondly, environmental competitiveness is a relative evaluation of the dynamic status of ecological environment. For any subject, only when the analysis on both the absolute value and the relative value are covered can we say that it is an overall analysis of the subject. Previous environmental economic theories mostly focused on analysis on the absolute value of environmental status, but environmental competitiveness analyzes the relative dynamic situation of ecological environment through comparison of different regions. Thirdly, environmental competitiveness cuts in from a very special angle to analyze ecological environment by borrowing the mechanism of force and action. Environmental value theory and environmental accounting theory analyze the efficacy and benefit of ecological environment, but environmental competitiveness analyzes the driving source of how ecological environment provides such efficacy and benefit, which not only allows prediction of changes in the efficacy and benefit, but also can find the cause for such changes. Finally, environmental competitiveness can do overall static and dynamic analysis on the regional ecological environment. Such comparative analysis could be against different regions in the same period of time as static analysis, or against the same region in different periods of time as dynamic analysis.

1.1.3 GEC is the continuation and deepening of competitiveness theory.

GEC inherits and continues competitiveness theory; at the same time, it deepens the contents of competitiveness theory. First, ecological environment system is a complex dynamically changing system. It is influenced by not only the variables within the system, but also by external factors such as human social system and economic development level; and, these influences show nonlinear relation, which makes the evaluation of the absolute status of ecological environment very difficult, or even impossible.
Competitiveness evaluation methodology puts emphasis on the evaluation of the relative and comparative ability of certain property of different matters by layer analysis, which means breaking down the various complex factors that influence such property, followed by analysis of each of them, and after adding weight, the comparative ability of this property of different matters will be obtained. Such feature of the evaluation suits well with the complexity and dynamic state of the system and therefore can appropriately evaluate the dynamic development of ecological environment in different regions. Secondly, GEC enriches and develops competitiveness theory. A review of the available literature shows that so far there has been not complete analysis on the connotation, mechanism formation, evaluation indicator system and projection methodology of GEC as a concept and neither there is complete analysis on the environmental competitiveness of different regions of the world. This study, therefore, will greatly enrich and develop the related competitiveness theory and analysis methodology.

1.1.4 GEC is the ability for sustainable development worldwide.

Environmental effect is actually the process of how natural environment acts on human beings and also human ability of how to protect and kindly treat the nature, which is ultimately expressed as how natural environment support and facilitate human survival and development and as an ability for regional sustainable development; it is the result of the operation of the dynamic system of the cyclic change of ecological environment. GEC is the result of comparing the environmental effects of different countries of the world; the relationship between GEC and environmental effect is the relationship of relative value and absolute value, sharing identical inherent connotation. First, GEC is natural environment's effect on humankind. Economy and environment are mutually influential and interactive, constituting an interdependent economy-environment system. Natural environment acts on humankind from three aspects: 1. Natural environment provides various material resources for human economic system (such as oil, mineral products and water); 2. Natural environment provides various services for human economic system (such as life support service and comfortableness service); 3. Natural environment is at the same time a place of purification for the residues of economic system. Therefore, evaluation of the current status of the natural environment's effect on humankind should include the evaluation of the capacity of natural environment to provide all kinds of resources (reflecting the resource supply capacity of environment), the capacity of natural environment to provide ecological service (reflecting the ecological service supply capacity of environment) and the capacity of natural environment to provide environmental purification (reflecting the purifying capacity of environment). Secondly, GEC is the capacity of humankind to protect and kindly treat the nature. Human economic activities will impose great pressure on natural environment and environmental governance and protection by human beings will also improve natural environment. Therefore, the evaluation of human capacity to protect and kindly treat the nature should include evaluation of the pressure of economic activity by human on natural environment (reflecting the coordinating capacity of environment and economic system) and human capacity to govern and protect environment (reflecting human capacity for
environmental governance). In the end, GEC is the interactive force between humankind and environment, appearing as natural environment supporting and facilitating human survival and development and the sustainable development capacity worldwide.

1.2 Reality Basis of GEC

The existence and development of GEC not only has sufficient theoretical basis, but also turns out to be necessary from the development realities faced by the world. The history of human development tells us that environment has always been the key factor for human survival and development, especially after industrialization when productivity witnessed unprecedented progresses and human influence over environment continued extending; thus environmental problems appeared and threatened the survival and sustainable development of human beings, with global climate change as the biggest problem. The world community has been well aware of the seriousness of these problems and started aggressive actions with some achievements, but there is still a long way to go to find the final solution for environmental problems. At present, solving environmental problem and realizing sustainable development are the common understanding and a development strategy for all countries of the world; it is foreseeable that environmental competitiveness will be a key component of national comprehensive competitiveness. To realize sustainable development must enhance global environmental competitiveness. The constraints of related environmental theories in practice call for new theory to provide guidance. These together constitute the practical basis of global environmental competitiveness.

1.2.1 Enhancing GEC is related to human survival and development.

In retrospection of the historical process of human development, we can find that the entire human history is the course during which humankind continues fighting with environment and get adapted to environment. Only by harmoniously co-existing with environment, can human beings survive and all countries can thrive; otherwise, death and declining wait. In the Quaternary Ice Age about 3 million years ago, the earth once encountered climate crisis, and it is during the process of solving this crisis that humankind came into being. At that time, climate was extremely cold and forest area decreased in large scale, which seriously threatened the survival of ancient ape and caused large quantity of deaths. But a few number of ancient apes changed habits of life. They stepped down from trees, learned to make and use tools, rebuild the environment and fight against coldness and hunger; thus humankind came into being.

Ancient humans could only live on collection and hunting and fishing during the very long process of development. As they didn't know how to build a well, they couldn't be far away from water source and thus the biotic resources available for collection and hunting or fishing were very limited; very often, depletion of biotic resource occurred because of excessive collection and fishing or hunting. Therefore, food crisis occurred too. This is an environmental problem that directly influenced production. Food crisis forced ancient humans to change again the lifestyle and production mode. In about 8,000 years ago, humans learnt
farming and raising livestock; human society entered a new stage, i.e. from primitive society to agricultural society.①

In agricultural society, production developed, living conditions were improved, and social civilization progressed in big steps; there appeared even great ancient civilizations like ancient Egypt, ancient Babylon, ancient Greece, ancient India and ancient China. But at the same time, new environmental problems occurred too. Owing to increasing growth of population, expansion of farming land destroyed vegetative cover, forests were laid down and grasslands were cultivated, followed by soil erosion and desertification; irrational irrigation further caused salinization. These were all destruction to land resources and in turn damaged the economic foundation of agricultural society. Thus some ancient civilizations declined, or forced to migrate to other areas. So, another environmental problem occurred--land crisis. So far the human society is still in the trouble of land crisis.

Entering industrial society, human capacity of production has made unprecedented progresses. In order to satisfy the unlimited desire, humans exploited enormous natural resources and the "three wastes" were recklessly discharged into environment. When the amount of discharge has accumulated to the degree beyond environmental capacity, pollution would be the result. Now environmental pollution and recession in the entire globe is already rather severe. According to the data in UNEP Yearbook 2009, there are currently 25 countries where the entire forest ecosystem has disappeared and another 29 countries with 90% of decrease in that. Since the 1960s, the biomass of major economic marine fishes has been reduced by 90%. Till the middle of this century, the available agricultural acreage per capita might be less than 0.1 hectare, which requires increase in agricultural productivity; yet that is not possible to be realized simply relying on traditional method. Climate change is another painful example. As the continually discharged greenhouse gases can't be "internally consumed", we have paid so high a cost that could hardly be imagined even a few years ago: the water reservoirs located in the Mediterranean and the Midwestern USA would soon be dried up; and the ice cover on Greenland is possibly disappearing at the speed of 100 cubic kilometers per year, leading to rising of sea level. The North Pole is no less than a big storage of methane. In the northwest of Svalbard, there are now more than 250 seething mantle plumes, a signal warning the coming of the "critical" point of earth's climate. ② All these indicate one thing that the present environmental problems have become a bigger threaten to the survival and development of human beings.

1.2.2 Enhancing GEC is a definite requirement of combat against climate change.

Although humans kept records about meteorological phenomena since as early as 1861, till the 1960s and 1970s were people aware that economic development accompanied with destruction of environment is not sustainable; excessive taking from the nature by humans would finally punish humans itself and

greenhouse effect is an apparent example. In 2007, the UN pointed out in IPCC Fourth Assessment Report that the possibility of attributing climate warming to the greenhouse gases discharged due to human activities has increased from 66% in the 2001 assessment to over 90%; influence of climate change covers all aspects of natural ecology and social economy, from water resource to food safety and human health, and to the root of global operation—energy. Former Chief Economist of World Bank Lord Stern indicated in his Stern Review: The Economics of Climate Change that climate change has caused an economic loss that might reach 5% to 20% of annual global GDP and may particularly impact the developing countries including China. In a word, climate change as an issue has completed a hop skip and jump from "scientific issue" to "political issue" and to "economic issue", and finally to the all-inclusive strategic height of "development issue".

Global warming is a complicated issue and people's understanding of the issue far from adequate; besides, as the causes and influences of global warming are worldwide, any effective policy or solution must rely on international covenant. The world community has made great efforts in this issue. The United Nations Framework Convention on Climate Change, Kyoto Protocol and Copenhagen Agreement are all important climate resilient legal documents, and the international system guarantee for the universe to jointly solve the historically most challengeable environmental externality problem. These all reflect the complexity and persistence of climate change; and tomorrow, the international community will have to put more efforts to solve this world issue.

Although the global negotiation process against climate change is not smooth, international conducts never stopped and the international system framework for the issue of climate change is foreseeable, which will eventually become a global agreement covering political, economic, social and cultural fields and, through international political and diplomatic channel, be transformed into legal obligations and policy of all countries with the efficacy like such international codes as the United Nations Charter and GATT. That means increasing global environmental competitiveness, energy-saving and emission reduction, increasing carbon sink, controlling emission of greenhouse gases, improving global climate, which will become compulsory obligations within legal system.

1.2.3 Enhancing GEC is the key part of enhancing the comprehensive competitiveness.

Green economy is the future direction of world economy. No matter at macro-level, meso-level or at micro-level, environment always influences almost all aspects of economy of a nation; in other words, global environmental competitiveness will be the key part of a nation's comprehensive economic competitiveness.

First, from the macro-level, the instrument to measure the overall economic level of all countries is still Gross National Product (GNP); but in fact, under the current sustainable development strategy, GNP is inappropriate, because it does not consider such problems as environmental pollution, resource depletion and social security caused by economic growth: in the first place, GNP does not calculate the loss caused by environmental damage; and in the second, the expenditures use to handle environmental pollution and
resource destruction are included in GNP. Therefore, specialists and scholars are all studying new economic accounting system that includes both natural resource and environment. Thus it can be seen that the level of environmental competitiveness will directly influence the general economic level of a nation.

Secondly, from the meso-level, green economy has already become the direction of future economic development. The Copenhagen Climate Change Conference held in 2009 has set the requirement that by 2020 emission shall reduce 30% from the base of 1990. According to the analysis of International Energy Agency, if by 2050 greenhouse gases emission were reduced to the level of 2005, the marginal emission cost per ton of CO$_2$ would reach $50; if by 2050 emission were reduced to 50% of 2005 level, the marginal emission cost would reach $200-$500 per ton of CO$_2$, which is equivalent to ¥$620-$2480 or even ¥$6200 of cost for each ton of coal. "Low-carbon economy" thus appears. It aims at reduction of greenhouse gas emission and establishment of economic development system based on low energy consumption and low pollution. This includes low-carbon energy system, low-carbon technology and low-carbon industrial system. Through levying carbon taxes on high-emission and high-carbon economies (such as coal, steel, non-ferrous metal, etc.) and transaction of Certified Emission Reduction (CER), subsidies for low-carbon or zero carbon emissions economies (primarily clean energy) and thus the objective of reducing CO$_2$ emission and solving climate problem can be reached, forming a low-carbon economic system. So to speak, green economy like environment-related low-carbon economy is the direction of future economic development.

Finally, from the micro-level, green competitiveness has already become the core competitiveness of enterprises. Core competitiveness is the source an enterprise to obtain and maintain competitive advantage; its characteristics are reflected in at least three aspects: particularly good for realizing customer-emphasized value; hard to be copied by competitor and hard to be replaced; persistence. Enterprise having green competitiveness would have advantage in realizing user's value compared with other enterprises, because, with people's requirement on the material standard of living getting higher, consumers show increasing preference to environment-friendly products and hence green products can bring more value to users. Moreover, the technology and knowledge implied by such value activities as green production, green design and green material supply makes green competitiveness something difficult to be copied by ordinary enterprises and thus help the enterprise maintaining persistent competitive edge. Today, when green consumption becomes a vogue, green itself becomes a commonly understood concept, green products are well accepted by the public and when green market extends wide, green competitiveness has become an important part of the core competitiveness of an enterprise, or even become one of the fundamental ability to survive and grow.

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② MBALib. Green Competitiveness of Enterprise [EB/OL]. http://wiki.mbalib.com/wiki/%E4%BC%81%E4%BB%9A%E7%BB%BF%E8%89%B2%E7%AB%9E%E4%BA%89%E5%8A%9B, 2010-06-6/2010-03-20.
1.2.4 Enhancing GEC is a practical choice to realize sustainable development.

Since the advent of humankind, she has established an inalienable close tie with environment. In retrospect of the historical process of human development, we can find that the entire human history is the course during which humankind continues fighting with environment and get adapted to environment. Only by harmonious coexisting with environment, can human beings survive and all countries can thrive; otherwise, death and declining wait. In the two or three million years of Paleolithic Age, primitive humans lived on hunting and fishing and collection simply relying on environment; till the Neolithic Age about 10,000 years ago, ancient humans began invention of simple tools to utilize environment and started agriculture and animal husbandry as well as handicraft activities like jade carving. Since then, especially about five thousand years ago, with the start of human civilization, driven by increase of population and continued progress of production technology, the area coverage by human colonization has been continually widened, followed by environmental problems. Particularly after humans entered industrial society, the pace of development has exceeded any time in history. When people enjoyed the benefit of economic growth, they have to face the increasingly severe environmental problems.

In the 1950s and 1960s, environmental problem began one of the biggest concerns of the public. Frequent environmental problems in developed countries have made related researches shift gradually from microscopic areas like resource depletion, pollution control and environmental protection to macro issues like resource environment system, and environment was tightly attached with economic development. The researches on environment problems also broke the geographic limitation within a country or region; it has become a problem to be faced and solved by the entire world.

Today, the influence of the international financial crisis is not yet cleared, and world economy is just at the turn of a new round of structural adjustment and the critical period for innovation development; global resource and environment issues will be a big challenge for the international community for a long period, such as climate change, energy security and biodiversity protection; and green development, circular economy and low-carbon economy are increasingly becoming the trend of development. Particularly after March 11, 2011, when the Fukushima nuclear disaster triggered by the earthquake and tsunami in Japan again stroke the bell for nuclear pollution, countries like USA, Europe, China and Korea successively detected artificial radioactivity substance in both air and ocean several days later. The hazard and consequence on environment and humankind due to this nuclear crisis are to be further assessed, but environmental issues like nuclear pollution and nuclear security undoubtedly become the focal issue of public concern again. Therefore, whether to confront the shock from world's new economic development, or the supportiveness of resource and environment, we must enhance environmental competitiveness and take it as the breaking point to optimize economic structure, accelerate the transformation of development pattern and to realize the transition from industrial economy to ecological economy; only so can a country take dominance in the new round of international competition.
1.2.5 Enhancing GEC is an innovation to overcome the limitation of environment related theories in practice.

Environment related theories are actually all from objective practice, which offer guidance and reference for assessment of and solution to environmental problems. But, as the historical context of researchers, the subject for study and the focus of research are different, some theories show apparent limitations. (1) Environmentology. It can tell us the constructive principle of environment, principle of various pollutions (water pollution, atmospheric pollution, soil pollution, noise pollution and ecological effect of environment pollution), the indicators and standards for judgment of the status of environmental pollution as well as environmental pollution control technologies. But, it is more research on the various principles and control technologies of environmental problems from the perspective of natural science; it can only tell us the current status of environmental pollution and under such circumstance what technologies to be adopted for governance. Here are two problems: first, environmental pollution is not solely caused due to technical reasons; actually, environmental economics already demonstrated that the root cause is the externality of environmental resource, but people do not thoroughly understand this. Just because of the dual effects of both market failure caused by externality and policy failure caused by inadequate understanding, environmental problems appeared. Therefore, environmental pollution governance should essentially be to correct the market failure and policy failure. Secondly, assessment and measurement of environment must include status, pressure and response, because environmental change is such a dynamic consecutive process, during which, when human activities impose certain pressure on environment, environmental status would change and the society should respond to such change to restore environmental mass or prevent environment from degradation. If the measurement and assessment only covers current status of environment, the dynamic change of environment can't be obtained. (2) Natural resource and environmental economics. It discussed the root cause of environmental problems from the socio-economic perspective, put forward various policies and economic means to control environmental problems, explored the value connotation of environment and proposed different types of methodologies for environmental assessment. But, these analyses must be established on the data of environmental status. So, natural resource and environmental economics need the theoretical support of natural sciences such as environmentology. In addition, although natural resource and environmental economics attempted including environment (resource) into the system of national accounts so as to establish appropriate sustainable development ability evaluation system, there is still no single final conclusion from the existing environment and economic comprehensive accounting; from related research results we observed that there are at least two weaknesses: 1. Simple natural resource accounting or roughly putting natural resource depletion value and ecological environmental degradation value into national accounts. This fails to differentiate economic value and ecological value according to its correlation to economic strength and its essential characteristic; thus confusion of the relationship between economy and environment might occur, which is kind of barrier to the provision of objective, systematic and
orderly baseline data for the establishment of policies regarding economy, natural resource, environment and other related price policies. 2. Roughly copying SEEA related concept of natural assets, which might lead to magnified comprehension of natural resource and misunderstanding of it, confused with concepts that are commonly used in economic sphere, such as economic assets and financial assets. Finally, environment and economic comprehensive accounting theory are already mature, but it can only be used to evaluate static regional sustainability, not the dynamic development trends of regional sustainability.
Chapter 2 Main GEC Research Contents

2.1 Connotations of GEC

2.1.1 Concept of GEC

Since the 1990s, environmental competitiveness as a concept was frequently used and gradually valued by people; but as the discussions about the concept was done in different angles, there has been no unified definition for the term. In a broad sense, environmental competitiveness has rich contents: it can be classified into natural environmental competitiveness and social environmental competitiveness by nature; or into national environmental competitiveness, regional environmental competitiveness, city environmental competitiveness, development area environmental competitiveness, industrial environmental competitiveness and enterprise environmental competitiveness by spatial dimension; or into tourism environmental competitiveness, ecological environmental competitiveness, investment environmental competitiveness, humanistic environmental competitiveness, living environmental competitiveness and talent environmental competitiveness by focal point.

GEC is a whole new way of weighing under the context of increasing contradiction between economic development and environmental protection. It takes competitiveness as the core supported by natural environment; technology innovation as the main instrument; market mechanism and government regulation as the means; bearing capacity-coordinating capacity-executive capacity-influencing capacity-contributing capacity as assessment basis; capacity-response-feedback-adjustment-optimization as main line; intensifying environmental development and utilization, reducing environmental damage, maintaining global ecological equilibrium and realizing global sustainable development as objectives; and ecological environment, resource environment, environmental bearing, environmental management and environmental coordination as contents. It reflects the environmental competitive capacity of different countries of the world in a comprehensive and systematic way.

The concept of Global Environmental Competitiveness proposed in this study is different from terms like green competitiveness, ecological competitiveness, energy competitiveness or low carbon competitiveness; it is neither attached to enterprise competitiveness, industrial competitiveness, regional competitiveness or national competitiveness. GEC is independent of and somewhat related to these concepts. Compared with the traditional competitiveness concepts, GEC emphasizes environment more as the basic element of human production and living; it places stress on the coordinated development of both human and environment and focuses on the existing and potential impact of environment.

2.1.2 Connotations of GEC

As given above, GEC is a huge comprehensive system involving economy, society and environment; it
can be divided into five aspects, as shown in Figure 3-2:

(1) Bearing Capacity. It reflects a nation or region's capacity of ecological and resource environment to bear the regional sustainable development. The area and space of the nation or region is limited, its environmental basis available for development and utilization is limited, and its capacity to bear pollutant is also limited. Environment with different size, structure and function will show different bearing capacity. But environmental bearing capacity is never unalterable. Through environmental protection and technological advancement, the capacity to bear the intensity and scale of development and utilization may be enhanced. At the same time, once environmental damage exceeds the highest threshold, it would influence environmental function and damage ecological balance, while recovery of the damage would require payment of high cost.

(2) Coordinating Capacity. It reflects a nation or region's capacity of ecological and resource environment to coordinate with the regional production and living activities. Environment provides the fundamental physical and spiritual conditions for normal production and living activities for humans, and digests and absorbs various pollutants generated by human activity; and human activity, particularly large-scale organized production activity, will also influence environment in aspects like earth surface formation, material cycle, heat budget and ecological balance. Coordinating capacity is an important component of environmental competitiveness; it may be adjusted and optimized by means of lifestyle transformation, readjustment of industrial structure and emission control. The stronger coordinating capacity is, the more harmonious the symbiotic relation between environment and human will be and the stronger environmental competitiveness will be.

(3) Executive Capacity. It reflects a nation or region's executive capacity of all levels of government to manage ecological and resource environment and so as to realize environmental optimization. Relying on the administrative, economic, legal, educational and technological management functions of all levels of government, with public participation and social supervision as supplement and by means of environmental monitoring, environmental inspection and environmental assessment, environmental pollution can be prevented and controlled, ecological environment can be protected and repaired, environment can be comprehensively optimized and environmental competitiveness can be enhanced. Executive capacity is shown in almost all links of production and life and the entire course of production-distribution-trade; focusing on innovation in technology, system and mechanism and combining both price and non-price instruments, it will gradually strengthen environmental competitiveness.

(4) Influencing Capacity. It reflects a nation or region's capacity of ecological and resource environment to influence neighboring regions and the capacity of human activity, especially major construction projects, to influence the regional internal environment. Influencing capacity comprehensively reflects the influencing capacity of regional natural environment and social environment through assessment of environmental quality status and impact; it is an important part to weigh environmental competitiveness. Such capacity
varies with the improvement in environmental management and management pattern, and also varies with the influencing capacity of surrounding areas.

(5) Contributing Capacity. It reflects a nation or region's capacity of existing, improved and damaged environment to make contributions to regional sustainable development. The quality of environment, efficiency of environmental management and implementation of major projects will directly influence the contributing capacity of environment. Vice versa, contributing capacity influences the bearing capacity of regional ecological and resource environment and the coordinating capacity between human and environment. Contributing capacity is the manifestation of the externality of GEC and core of GEC.

In summary, the concept of GEC used in this study has the following characteristics: (1) It considers both existing environmental competitiveness and the potential impact of environmental change; (2) It mainly investigates natural environment and its contents have overlapping areas with ecological environment and hard environment; (3) It also investigates the impact on all nations inside and outside the region by environmental quality improvement under the concept of environmental protection; (4) It considers the multi-layer superimposed effects of implementation of environmental protection under the current global environmental status.

![Figure 2-1 Connotation of GEC](image)

2.2 Compositions of GEC

2.2.1 Component Elements of GEC and Their Functions

Based on the research results on GEC, the component elements of GEC in this study include five parts, i.e. ecological environmental competitiveness (EEC), resource environmental competitiveness (REC), environmental bearing competitiveness (EBC), environmental management competitiveness (EMC), and environmental coordination competitiveness (ECC).
2.2.1.1 Ecological environmental competitiveness (EEC)

Ecological environmental competitiveness (EEC) is the basic element of GEC. Ecological environment is the main component that attracts inhabitants and capital input and also an important factor that influences environmental competitiveness in long term. The cost to obtain ecological environment is very low; but once damaged, the cost for recovery is huge. Ecological environment includes natural ecology, rural ecology, biodiversity and biosafety. On the one hand, EEC looks at the utilization efficiency of ecological environment during the course of production and living, mainly shown as indicators like emission quantity and industrial added value ratio, pesticide and fertilizer consumption and available irrigation area; on the other hand, it also looks at the intensity of ecological environmental protection, mainly shown as indicators like amount and area of public park, green surface and natural reserve used. ECC should reflect not only the contributing capacity of ecological environment for human activity, but also the utilization intensity and level of ecological environment by humans; it also reflects the degree of emphasis put by humans on ecological environment; it is the assessment basis of GEC.

2.2.1.2 Resource environmental competitiveness (REC)

Ecological environmental competitiveness (EEC) is the fundamental condition of GEC. Resource environment includes water environment, land environment, atmosphere environment, forest environment, mineral product environment and energy environment; it is the existing element of GEC and provides necessary support for human production and living. Water environmental competitiveness looks at the amount of existing water resource, its utilization efficiency and pollution status; land environmental competitiveness looks at the quantity intensity of using farming land, garden plot and construction land; atmosphere environmental competitiveness looks at the pollutant discharged by industrial activity into atmosphere; forest environmental competitiveness looks at the situation of forest utilization and plantation; mineral product environmental competitiveness looks at the reserve status of mineral resources; energy environmental competitiveness looks at the status of energy production, consumption and utilization. REC is an internal element of GEC and the necessary guarantee to form GEC; it comprehensively reflects environmental capacity to bear human production.

2.2.1.3 Environmental bearing capacity (EBC)

Environmental bearing capacity (EBC) is an important aspect to weigh the strength of GEC. Environmental bearing involves industrial production, agricultural production, energy consumption and climate change; it reflects a nation or region's capacity of ecological and resource environment to bear regional sustainable development and also human activity's influence on natural environment, or, the response and restorability of environment against human activity; it is an important indicator to weigh the strength of environmental competitiveness. Again, EBC is never unalterable. Through environmental protection and technological advancement, the capacity to bear the intensity and scale of development and utilization may be enhanced. At the same time, once environmental damage exceeds the highest threshold, it
would influence environmental function and damage ecological balance, while recovery of the damage would require payment of high cost.

2.2.1.4 Environmental management competitiveness (EMC)

Environmental management competitiveness (EMC) is a powerful support to GEC. Government and the public are the key players of environmental management; it coordinates the supervision relationship between socioeconomic development and environmental protection by various administrative instruments and economic and legal means. EMC includes two aspects, resource utilization and environmental safety, used to show utilization efficiency and environmental pollution governance results respectively. On the one hand, EMC needs economic and non-economic input to guarantee the smooth execution of environmental management and execution intensity of such; on the other hand, environmental management efficiency can only be observed after long-term observation. EMC comprehensively reflects the executive capacity for environmental governance; it is an important step to enhance GEC.

2.2.1.5 Environmental coordination capacity (ECC)

Environmental coordinating capacity (ECC) is an important assessment reference for GEC. Population, economy, society and environmental coordinated development are the important criteria to judge the superiority or inferiority of environmental competitiveness and also an important way to realize the objective of sustainable development. ECC is present via the relation between population and ECC and economy and ECC. ECC can be optimized with improvement in production technology, readjustment of production structure and transformation of lifestyle. It is the external factor that influences GEC and also an important guarantee for formation of GEC; it even influences the changes in GEC.

2.2.2 Internal Relations of GEC Elements

The formation of GEC is a dynamic complex process. EEC, REC, EBC, EMC and ECC are the foundation stones of GEC and at the same time an important link to influence GEC. The objectives of these five elements are to increase the efficiency of environmental development and utilization, reduce environmental damage, maintain global ecological balance and realize socioeconomic sustainable development; through economic and administrative means, it can comprehensively reflect and influence environmental competitiveness.

EEC and REC reflects environmental bearing and contributing capacity by the way of capacity-response; they are the foundation and guarantee of the management, bearing and coordinating competitiveness of environment. Without ecological and resource environment, human production and living would have no support, not to mention utilization and protection of environment. And, for ecological and resource environmental protection and governance by means of various administrative and economic policies, system and mechanism, the process and effect receive feedback through environmental management and bearing competitiveness and they are kept under readjustment and improvement based on the representation. The ultimate objective of improving environmental quality is to promote the harmonious
unification of humankind and environment, and to realize the sustainable development of both; this is the essential contents to be reflected by ECC and the key part where environmental optimization lies (See Figure 3-3). Therefore, EEC, REC, EBC, EMC and ECC are never mutually independent units; instead, they are an interactive unity focusing on the main line of capacity-response-feedback-adjustment-optimization. Appropriate degree of enhancement and collaboration of the five elements can push the overall enhancement of GEC.

![Figure 2-2 GEC Elements and Their Internal Relations](image-url)
Chapter 3 GEC Indicator System/Mathematical Model Design & Evaluation Methodology

In order to objectively evaluate the level of GEC and understand all the aspects and internal mechanism of GEC, a comprehensive evaluation of it is necessary, which requires establishment of an indicator system that can objectively and precisely reflect the various aspects of GEC while at the same time looking at the internal structural characteristics of it and can evaluate and analyze it using scientific and logical mathematical evaluation model. Owing to the extensive contents covered by GEC, including ecological environment, resource environment, environmental management, environmental influence and environmental coordination, and the unique internal structural characteristics, it is a rather complex task to establish an indicator system and mathematical model used for evaluation, analysis and research of the GEC. This study has explored to design a scientific and proactive evaluation indicator system and model with reasonable logics and wide visual field and at the same time fitting into the reality of global environment based on the environmental status and facts of 133 countries of the world and their environmental development objectives.

3.1 Construction of GEC Indicator System

With adequate understanding of the intrinsic composition and characteristics of GEC as well as the principles to be followed, we may start the work of constructing the GEC Evaluation Indicator System.

3.1.1 Methodology

Based on the connotations, intrinsic composition and characteristics of GEC and according to the requirements of global sustainable development, this study has constructed a multi-layer and multi-system GEC Indicator System with classified categories, and divided the indicators into four layers of system layer, module layer, factor layer and foundation layer (corresponding to primary, secondary, tertiary and quaternary indicators) following the six principles and the rationale behind such top-down hierarchical division is system theory and control theory. The specific flow of thinking is shown in Figure 4-2.

Based on the theories about environmental sciences, ecology, environmental economics and sustainable development, the objective, significance and system layering of GEC is made clear according to its connotation, internal mechanism and characteristics and then the representative, pertinent and operable evaluation indicators are selected after careful analysis and comparison as well as consideration of the availability of data; thus the analytical framework and layered indicators for GEC evaluation are constructed.
and the meaning as well as measuring method for each indicator are also defined.

Then, by using frequency statistical method and Delphi method, the evaluation indicator system is further optimized to ensure the scientific and authoritative property of the indicators. To be specific, a statistical frequency counting is first done regarding the research reports and papers about sustainable development evaluation, ecological environmental quality evaluation and environmental competitiveness evaluation and then selects the indicators with high frequency of usage, such as Proportion of land area covered by forest, water resources per capita, Arable land per capita, etc. These indicators can reflect regional environment-friendliness and mostly data are available; thus these are good for indicators to measure the environment friendliness in evaluation. On top of this, Research team invited over 50 experts from environmental protection authority, social sciences academy, governmental development research center and the university domestic and overseas, meanwhile, we asked the environmental experts in the field of economy for advice who participated in “International workshop on Green Economic Transformation and Environmental Competitiveness Indicators” which held by UNEP, Chinese Academy for Environmental Planning, Division of Environmental Strategy, PRCEE, Fujian normal university to form an expert panel and the panel use Delphi method to do additions and deletions and improvement on the indicator system after discussions in meetings; a survey form of indicator weight is also designed for all layers. The experts are listed in the preface, and most of them sent back the survey form, which make the foundation for decision the indicator weight.

Next, a quantized mathematical model is decided according to the indicator system established in the previous step and the specific weight of each indicator is calculated; at the same time, quantization method and quantity calculation method for specific indicator as well as the detailed procedures are also defined; then a computer program is compiled.

Finally, input the regional indicator data to simulate the system and test the results. If the test results are justifiable, then the final GEC evaluation indicator system will be confirmed; if unjustifiable, the research team will further modify the indicator system and do system simulation again after modification.
3.1.2 Selection of Indicators in System Layer and Module Layer

There is only 1 indicator in the system layer of GEC evaluation indicator system (index), i.e., Global Environmental Competitiveness (GEC, A1). This is a comprehensive and systematic index to evaluate global environmental competitiveness, covering the various aspects of an environmental system as general outline and reflects the overall level of environmental competitiveness of a country; it is also the general objective of evaluation for the indicator system.

Below the system layer is module layer, in which indicators are actually the sub modules of an environmental system reflecting respective support to the environmental system. As per the composition,
mechanism and characteristics of GEC, the module indicators are designed from the five key component parts of GEC, namely REC, EEC, ECC, EMC and EHC, as five sub-index which constitute the major aspects and framework of GEC, as shown in Figure 4-3.

(1) **Resource Environmental Competitiveness (REC, B1)**. Resource is the most fundamental condition for human existence and development and also the basic element for socioeconomic activities. Utilization of resources will not only influence the balance of resource supply, but also affect the balance of environmental system and might further cause deterioration of the foundation for human existence and development due to environmental damage and pollution out of overuse and disuse of resources. REC reflects a region's strength in resource material basis; it is the basal indicator to measure the strength of GEC.

(2) **Ecological Environmental Competitiveness (EEC, B2)** Ecological environment refers to the entirety of various ecosystems that are composed of biotic communities and, mainly or completely, abiotic natural factors, and that indirectly and potentially impact human existence and development in the long run; it is the key part of natural environment. EEC mainly reflects the effect of both nature and humans themselves on ecological environment; it is an important label to indicate GEC strength.

(3) **Environmental Carrying Competitiveness (ECC, B3)**. Environmental Carrying refers to the effects of human activities (economic and social activities) on environment and the changes in environment cause by such activities, such as environmental quality worsening due to natural environmental pollution and damage during human production and life process, including low-efficiency and uncontrolled exploitation of natural resources, discharge of waste water, waste gas and waste solids into the natural world without strict treatment, etc. EBC reflects the impact of human activities on natural environment in a region, or...
environment's ability to respond to and restore itself against human activity; it is an important indicator to show GEC strength.

(4) Environmental Management Competitiveness (EMC, B4). Environmental management refers to a comprehensive action of human by using various means of planning, organizing, coordinating, control and supervision for the purpose of anticipated environmental objectives, mainly positive effects applied on natural environment, such as environmental pollution governance. Environmental management can timely discover and correct the problems in environmental system running, making environment operate normally and improving environmental status. EMC reflects a region's intensity in natural environment governance and supervision; it is a key indicator to measure GEC.

(5) Environmental Harmony Competitiveness (EHC, B5). Environmental harmony refers to the degree of harmony between the existence and development of humans and the environment, mainly including two aspects, namely coordinated development of population and environment, and coordinated development of economy and environment. EHC reflects the degree of coordination between human activities and natural environment in a region and also an important indicator to measure GEC strength.

3.1.3 Selection of Indicators in Factor Layer

Indicators in factor layer are the major factors that influence the sub-index and therefore are decided by the contents and features of each submodule. As per the connotations, composition and characteristics of the five sub-index; the factors are further subdivided to 16 pillars. Establishment of indicators in the system layer, the module layer and the factor layer has formed the main framework of GEC, as shown in Figure 4-3.

(1) Pillars under REC. Resource environment mainly includes four factors, land, water, forest and energy; therefore Land Resources (C11), Water Resources (C12), Forest Resources (C13) and Energy Resources (C14) as the pillars of GEC. Land, water, forest and energy are the most fundamental resources for human existence and development and also the basic elements for consumption required by the social and economic activities of human; they are the carrier of the entire human production and life and the environment constituted by these factors are the place where human society exist and where human interference and damage are most serious. Today, the resource environmental pollution and damage has become one of the key issues faced by the world. Land resources, water resources, forest resources and energy resources reflect the resource support to production and life from the angles of different type of resources in a region; they are the fundamental components of REC.

(2) Pillars Indicators under EEC. EEC mainly reflects the competitiveness in biodiversity and ecological safeguard and air quality are selected as the factor indicators under EEC. Biodiversity refers to the steady ecological complex composed of various live organism (animal, plant and microorganism) incorporated in regular pattern. It reflects the abundance of biotic resources and also the intricate relations between biotic lives as well as between environments; it even reflects the degree of human influence on ecological system. Ecological Safeguard reflects the effects of ecological recovery and reconstruction in a
region; it has big impact on ecological environmental competitiveness. Air Quality reflects the degree of air contamination; It is judged on the basis of pollutant concentration in the air, it is an important part of EEC.

(3) Pillars under ECC. Environmental Carrying mainly reflects the scale and scope of human activities; such economic activity need to consume natural resources on the one hand and has certain influence on the ecological environment on the other. The capacity of environment to support and carry human activity decides the sustainability of good environment. Therefore, four pillars are selected under ECC, agricultural carrying, industrial carrying, energy consumption, greenhouse gas. Agricultural production is the key source of food and other consumer goods and such activities inevitably requires development and protection of land resources; it is one of the most direct factors that influence ecological environment. Industrial production is the most important part of economic activity and the major aspect that consumes resources and damages environment. The production level and industrial structure in all countries are different and therefore environmental bearing capacity also shows big difference; hence varied influence on EBC. Energy is the motive power of economic activity. At present, the industrial development pattern relying on consumption of fossil energy not only requires exploitation and consumption of large quantity of energy, but also emits greenhouse gases that have a strong impact on climate environment. The ecological disasters caused by climate change and the impact on human activity have attracted worldwide attention. Greenhouse gasses emission increase is the leading cause for climate change; emission control not only reflects the economic structure of a country, but also reflects a country's efforts in response to climate change.

(4) Pillars under EMC. Environmental management mainly involves rational utilization of resources and protection of ecological environment, the factor indictors under this aspect are environmental governance, environmental protection and resource utilization. Modern economic operation can't do without exploitation, allocation and use of natural resources. Some resources are renewable, but many more resources are non-renewable. Excessive exploitation of renewable resources would cause non-renewability. Therefore, any country need to ensure that resource utilization is rational and controlled and continue optimizing resource allocation to increase utilization efficiency. Human activity keeps discharge different kinds of waste into the external environment, including the byproducts and waste of industrial and agricultural production and also the disposables generated during people's daily life. Establishment of waste discharge regulation and supervision are the preconditions to guarantee no pollution or damage to the environment on which human existence and development lie and also an important aspect to measure a country's environmental management capacity.

(5) Pillars under EHC. Environmental harmony mainly involves two aspects, the harmony between human and environment and the harmony between economy and environment, which become the two factor indicators under EHC. Harmony between population and environment refers to scientific planning of population development to promote moderate population growth and rational distribution as well as coordinated development of both population and environment, while taking environmental bearing capacity
into consideration. Population and environment harmony competitiveness reflects the degree of harmony between population development and environmental protection in a region; it is an important indicator to evaluate EHC. Harmony between economy and environment refers to adequate consideration of environmental protection while guaranteeing necessary economic development, adopting low-pollution and environment-friendly way of production and life as much as possible, so that the influence of economic growth on environmental quality can be controlled within the range of bearing capacity and that economy and environment can reach balance. Economy and environment coordination competitiveness reflects the degree of harmony between economic development and environmental protection in a region; it is also an important part of EHC.

### 3.1.4 Selection of Indicators in Foundation Layer and Description

Foundation layer is composed of individual indicators with direct measuring capacity, directly showing the measurement of indicators in factor layer; it is the most basic layer and operation layer of GEC indicator system. The evaluation of the entire indicator system is actually carried out in this layer. As per the defined scope of pillars, there are 60 designed individual indicators, as shown in Table 4-1.

GEC Evaluation Indicator System is composed of four layers, system layer, module layer, factor layer and foundation layer, which corresponds to 1 index, 5 sub-index, 16 pillars and 60 individual indicators; among these, the index, sub-index and pillars are indirect synthetic indicators, while individual indicators are direct objective indicators that are measurable and therefore will use the data released in current statistics system by such international organizations as UN and World Bank to guarantee the comparability of the collected data. As the statistical data about environment are limited and incomplete in current statistical system, which, to some degree, influences the availability of quaternary indicator data, certain relatively irrelevant individual indicators are already deleted while constructing the indicator system; but as for the few important and indispensable indicators, data will be collected using synthetic or substitute indicator. Such treatment might influence the precision and objectiveness of the evaluation result, but as the number of such indicator is extremely small and they are distributed in the bottom layer carrying small weights, there would be no obvious impact on the final overall evaluation result. The establishment of environmental competitiveness evaluation indicator system will provide a relatively reasonable and objective standard for the evaluation of GEC.

### 3.2 Construction of GEC Model Based on Modified AHP

After construction of GEC evaluation indicator system, the next step is to construct a GEC mathematical model, which is a step of vital importance during the evaluation process. Once the model is established, the evaluation process only requires input of collected data into the model and result will be obtained. Construction of the model can be done in three steps: first, apply dimensionless treatment to the evaluation indicators; next, determine the weights of indicators; and finally, establish the mathematical
model. In the second step, indicator weights will be determined using Delphi--modified analytic hierarchy process.

3.2.1 Dimensionless Treatment to Indicators

As the unit of measurement and dimension of each indicator (quaternary indicators) are different and very often the numerical values show wide gap, calculation can't be done directly; instead, we must first apply dimensionless treatment to the indicators, changing them into non-dimensional numerical value or point value by indexation for integrated computation. There are multiple non-dimensional methods, and there are four commonly used ones: normalization by aggregation, normalization by standard deviation, normalization by max value and normalization by range. Here we adopt simple and practical efficiency coefficient method to apply this treatment to the indicators.

When an indicator is a positive indicator (having positive influence on the upper-layer indicators), the non-dimensional value of Indicator i will be Xi:

\[ Xi = \frac{x_i - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \times 100 \]

When an indicator is a negative indicator (having negative influence on the upper-layer indicators), the non-dimensional value of Indicator i will be Xi:

\[ Xi = \frac{x_{\text{max}} - x_i}{x_{\text{max}} - x_{\text{min}}} \times 100 \]

In which, \( Xi \) represents the obtained non-dimensional value of Indicator i, Non-dimensional Indicator i for short; \( x_i \) is the original value of the indicator, \( x_{\text{max}} \) and \( x_{\text{min}} \) represent the maximum and minimum original values of similar indicators under comparison respectively.

After dimensionless treatment, the value of each indicator will be within the range of 1-100, with consistent polarity.

3.2.2 Assessment of Indicator Weight

Indicator weight represents its contribution to the evaluation objective in the indicator system; assessment of the weight of each indicator is a rather difficult procedure of the evaluation process and has vital importance for the results; therefore, the method used must be objective. Generally speaking, the most common way to assess indicator weight is using Delphi--analytic hierarchy process, i.e. first marking of the confirmed evaluation indicators through survey by experts based on and their long years of professional experience after pairwise comparison of the significance of each indicator and then calculation using analytic hierarchy process. Here the Delphi--modified analytic hierarchy process will be used to assess the weights. Modified analytical hierarchy process and the traditional analytical hierarchy process differ mainly in the scaling method for experts' marking while using Delphi method to arrange the evaluation indicators' relative importance judgment matrix. In traditional AHP, 1-9 scaling is adopted. But due to the complexity and
fuzziness of indicator, it is difficult for experts to make precise assessment on each indicator into the 9 grades of the 1-9 scale; instead, they may give relatively fuzzy judgment of the indicators' relative importance. For example, Indicator A is more important than Indicator B, but how much more important is not clearly given. The judgment matrix obtained this way is less accurate and needs several times of adjustment. Therefore, the AHP is modified to adopt the scale of 0-2, which is less time-consuming and convenient, and more acceptable to experts (CHENG Jian-quan, 2002). 0-2 Scaling is to first form a comparison matrix $B$, in which $b_{ij}$ is defined as:

$$
B = (b_{ij})_{n \times n}
$$

\[
\begin{align*}
    b_{ij} = \begin{cases} 
        2 & \text{When Factor } i \text{ is more important than Factor } j \\
        1 & \text{When Factor } i \text{ is equally important as Factor } j \\
        0 & \text{When Factor } j \text{ is more important than Factor } i 
    \end{cases}
\]

Next calculate $r_i = \sum b_{ij} (i = 1, 2, \ldots, n)$, i.e. summation by row, and then obtain the judgment matrix $C = (c_{ij})_{N \times N}$ using the following formula, in which $r_{\max} = Max\{r_i\}$, $r_{\min} = Min\{r_i\}$

and $b_m = r_{\max} / r_{\min}$.

\[
C_{ij} = \begin{cases} 
    \left[\left(\frac{r_i - r_j}{r_{\max} - r_{\min}}\right) \times (b_m - 1) + 1\right]^{-1} & r_i \geq r_j \\
    \left[\left(\frac{r_j - r_i}{r_{\max} - r_{\min}}\right) \times (b_m - 1) + 1\right]^{-1} & r_i < r_j 
\end{cases}
\]

After establishment of judgment matrix, other procedures shall follow the traditional AHP and finally the weight of each indicator can be obtained. The procedures of modified AHP are shown in Figure 4-4.
Based on these procedures, we sent the GEC Indicator System Weighting Survey Form for Experts to more than 50 scholars doing related researches in the academic circle and experts from government authorities; all experts are required to fill in the survey form independently and rate of return is 100%. Through reorganization of the survey forms and deducting the highest and lowest weighting results, the weights of all indicators are obtained from the average of the remaining weighting results followed by test. The finally tested environmental competitiveness indicator weight system is shown in Table 4-1.

**Table 3-1 GEC Quaternary Indicator System**

<table>
<thead>
<tr>
<th>Secondary Indicators (5)</th>
<th>Weight</th>
<th>Tertiary Indicators (16)</th>
<th>Weight</th>
<th>Quaternary Indicators(60)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Environment Competitiveness</td>
<td>0.2</td>
<td>Land Resources</td>
<td>0.2</td>
<td>Land area per capita</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Percentage of arable land to total land area</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Arable land per capita</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water Resources</td>
<td>0.3</td>
<td>Surface water</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Annual precipitation</td>
<td>0.25</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Groundwater</td>
<td>0.25</td>
</tr>
<tr>
<td>Category</td>
<td>Subcategory</td>
<td>Measure</td>
<td>Weight</td>
<td></td>
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<td>-----------------------------------------</td>
<td>------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total internal renewable water resources</td>
<td>Forest Resources</td>
<td>Growing stock in forest and other wooded land</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proportion of land area covered by forest</td>
<td>0.30</td>
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<tr>
<td></td>
<td></td>
<td>Forest area per capita</td>
<td>0.40</td>
<td></td>
<td></td>
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<tr>
<td>Energy Resources</td>
<td></td>
<td>Fossil energy</td>
<td>0.30</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Energy production</td>
<td>0.35</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Proportion of combustible renewables and waste to total energy consumption</td>
<td>0.20</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Net energy imports of the energy consumption</td>
<td>0.15</td>
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<tr>
<td>Ecological Environment Competitiveness</td>
<td>Biodiversity</td>
<td>threatened fish species</td>
<td>0.20</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>threatened mammal species</td>
<td>0.20</td>
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<td></td>
<td></td>
<td>threatened plant species</td>
<td>0.20</td>
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<tr>
<td></td>
<td></td>
<td>GEF benefits index for biodiversity</td>
<td>0.40</td>
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<tr>
<td>Ecological Safeguard</td>
<td>Ecological Safeguard</td>
<td>Terrestrial protected areas</td>
<td>0.60</td>
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<tr>
<td></td>
<td></td>
<td>Marine protected areas</td>
<td>0.40</td>
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<tr>
<td>Air Quality</td>
<td></td>
<td>Inhalable particles (PM10)</td>
<td>0.20</td>
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<tr>
<td></td>
<td></td>
<td>Particulate matter (PM2.5)</td>
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<td></td>
<td></td>
<td>Index of Indoor air pollution</td>
<td>0.30</td>
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<tr>
<td></td>
<td></td>
<td>Nitrogen oxides emission</td>
<td>0.15</td>
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<tr>
<td></td>
<td></td>
<td>Sulfur dioxide emission</td>
<td>0.15</td>
<td></td>
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<tr>
<td>Environment Carrying Competitiveness</td>
<td>Agricultural Carrying</td>
<td>Cereal yield per unit of arable land</td>
<td>0.40</td>
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<tr>
<td></td>
<td></td>
<td>Fertilizer consumption per unit of arable land</td>
<td>0.30</td>
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<tr>
<td></td>
<td></td>
<td>Annual freshwater withdrawals for agriculture per unit of arable land</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial Carrying</td>
<td>Net exports of goods as a percentage of GDP</td>
<td>0.25</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Electric power consumption per unit of value added of industry</td>
<td>0.25</td>
<td></td>
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</tr>
<tr>
<td>Environment Management Competitiveness</td>
<td>Energy Consumption</td>
<td>Greenhouse Gas</td>
<td>Environmental Governance</td>
<td>Ecological Protection</td>
<td>Resource Utilization</td>
</tr>
<tr>
<td>----------------------------------------</td>
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<tr>
<td>Energy Consumption 0.2</td>
<td>SO2 emissions per unit of value added of industry 0.25</td>
<td>Annual freshwater withdrawals for industry per value added of industry 0.25</td>
<td>Energy consumption per unit of land area 0.25</td>
<td>Ratio of clean energy consumption 0.25</td>
<td>Elasticity of energy consumption 0.25</td>
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<td></td>
<td>Elasticity of electric power consumption 0.25</td>
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<td></td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
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<tr>
<td>Greenhouse Gas 0.2</td>
<td>Growth rate of CO2 emissions 0.40</td>
<td>Growth rate of Methane emissions 0.20</td>
<td>CO2 emissions per unit of land area 0.20</td>
<td>CO2 emissions per unit of energy consumption 0.20</td>
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<td>0.2</td>
<td>0.2</td>
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<td>0.4</td>
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<td></td>
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<tr>
<td>Environment Management Competitiveness 0.2</td>
<td></td>
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<tr>
<td>Environmental Governance 0.3</td>
<td>Agricultural chemicals regulation 0.40</td>
<td>Percentage of the rural population with access to an improved water source 0.30</td>
<td>Percentage of the urban population with access to an improved water source 0.30</td>
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<td></td>
<td>0.3</td>
<td>0.3</td>
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<tr>
<td>Ecological Protection 0.4</td>
<td>Area of plantation and afforestation 0.40</td>
<td>Biome protect 0.30</td>
<td>Overfishing of fishing resources 0.30</td>
<td></td>
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<tr>
<td></td>
<td>0.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource Utilization 0.3</td>
<td>Utilization rate of water resources 0.25</td>
<td>Percentage of total internal renewable water resources to total water resources 0.25</td>
<td>Percentage of agricultural land to total land area 0.25</td>
<td>Percentage of fossil fuel energy consumption to total energy 0.25</td>
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<td></td>
<td>0.3</td>
<td>0.3</td>
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</tbody>
</table>
### 3.2.3 Establishment of GEC Model

After weighting of indicators, next step is to construct the GEC model for calculation of the GEC evaluation score of each country. The higher the evaluation score, the stronger the country’s environmental competitiveness will be. The GEC model is determined as:

\[
Y = \sum_{i=1}^{l} \sum_{j=1}^{m} \sum_{k=1}^{n} x_{ijk} W_{jk} \\
Y_{i}^{1} = \sum_{j=1}^{m} \sum_{k=1}^{n} x_{ijk} W_{jk} \\
Y_{ij}^{2} = \sum_{k=1}^{n} x_{ijk} W_{jk}
\]

In which, \(Y\) is the GEC comprehensive evaluation score, \(Y_{i}^{1}\) is the evaluation score of Module Indicator \(i\), \(Y_{ij}^{2}\) is the evaluation score of Factor Indicator \(j\), \(x_{ijk}\) is the non-dimensional data value of Foundation Indicator \(k\) under Factor \(j\) in Module \(i\), \(W_{jk}\) is the weight of this Foundation Indicator, \(l\) represents the number of Module Indicators in the GEC indicator system, \(m\) is the number of Factor Indicators in each Module Layer, and \(n\) is the number of Foundation Indicators in each Factor Layer.

<table>
<thead>
<tr>
<th>Environment Harmony Competitiveness</th>
<th>Population and Environment</th>
<th>0.5</th>
<th>Percentage of population with access to Improved sanitation facilities</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motor vehicles per 1000 people</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Renewable internal freshwater resources per capita</td>
<td>0.15</td>
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<td></td>
<td></td>
<td></td>
<td>SO2 emissions per capita</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CO2 emissions per capita</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy consumption per capita</td>
<td>0.15</td>
</tr>
<tr>
<td>Economy and Environment</td>
<td></td>
<td></td>
<td>Land resource utilization efficiency</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sulfur dioxide emissions per unit of GDP</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon dioxide emissions per unit of GDP</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy consumption per unit of GDP</td>
<td>0.25</td>
</tr>
</tbody>
</table>
With the GEC model, evaluation of a country's environmental competitiveness becomes a simple job, because the weight of each indicator is fixed and the only thing to be done is to input the non-dimensional data value of the Foundation Indicators of the country; then the GEC score as well as the scores of each Module Indicator and Factor Indicator can be obtained. The model can also carry out comprehensive evaluation on each country's environmental competitiveness; all countries can be ranked, compared and analyzed according to respective comprehensive evaluation scores.

3.3 Method of Determining GEC

3.3.1 Definition of GEC Evaluation Period and Area Coverage

Due to various restrictions during GEC evaluation, it is not possible to evaluate the environmental competitiveness of all countries or regions in any time period; therefore, it is necessary to first define the time period and area coverage of the evaluation.

(1) Evaluation Period. As per the internationally released public statistical data, the latest data year is 2010 and therefore the benchmark year of GEC evaluation is also decided as 2010.

(2) Evaluation Areas. Based on the collected data, the evaluation and analysis of the environmental competitiveness in this study are done for the 133 countries of the world. And these countries are classified according to the six continents of Asia, Oceania, North America, South America, Europe and Africa; comparative analysis is also done for G20 nations and five BRICK countries.

3.3.2 Indicator Ranking Sections

Base on the tested indicator system, this study adopts radar chart to complete the evaluation and comparative analysis on each layer of GEC indicators. For the convenience of evaluation result analysis, the rankings are sectionalized. To judge a country's environmental competitiveness level around the globe, the rankings are divided into five sections, $1^{\text{st}}-10^{\text{th}}$, $11^{\text{th}}-30^{\text{th}}$, $31^{\text{st}}-60^{\text{th}}$, $61^{\text{st}}-100^{\text{th}}$ and $101^{\text{st}}-133^{\text{rd}}$.

3.3.3 Analysis of Indicator Scores

GEC is composed on five Sub-index and the GEC comprehensive score is obtained from the collective of the five scores; and each countries show varied performance in the five Sub-index. In order to better demonstrate such variation, the contribution rate of each Sub-index to environmental competitiveness is measured and calculated, so as to show the strengths and/or weaknesses of a country's environmental competitiveness.

\[ Y_i = \left( Y_i^l \times w_i \right) / Y \]

Here $Y_i$ represents the contribution rate of Sub-index i to comprehensive score, $Y_i^l$ and $Y$ are defined in Formula 4.1-4.3, as the evaluation score of Sub-index i and the comprehensive evaluation score of GEC, and $w_i$ represents the weight of Sub-index i in index. The contribution of five Sub-index to the index is
given in Figure 4-5 as pie graph.

Figure 3-5  Contribution of Sub-index Scores

At the same time, in order to see the scores of pillars and their performance in the countries, the highest and lowest scores of each pillar is also calculated; the rankings of all pillars can better show their comprehensive performance. As shown in Figure 4-6, the dark line corresponding to each of the pillar represents the distribution of this indicator in different countries; the hollow triangle in the middle is the country's ranking place.

Figure 3-6 Tertiary Indicator Scores
Chapter 4 Technical Roadmap of GEC Evaluation & Analysis

4.1 General Research Organization and Contents

4.1.1 Research Framework

GEC research is a whole new area, therefore, such researches need to first summarize the related previous researches and then extend the research with more contents and innovation in methodology. GEC is a cross-discipline research involving multiple areas of environmental economics, biology, economics and sociology, which are intricately interrelated; at the same time, we need to rationally define and objectively evaluate GEC, and make innovations in methodology. In this way, we can thoroughly explore the inherent essence of GEC and reveal the laws of GEC evolution. For such a complicated research subject, it requires clear organization and correct research approach, strictly following the designed technical roadmap (See Figure 5-1) to ensure satisfaction of research standards and quality.

In terms of contents, through substantial literature review and reference to theories about environmentology, economics and management science, the significance and necessity of GEC research is profoundly discussed from different angles; the key contents of this research is to construct the GEC theory system based on the results of previous international researches. Particularly, as a new research area, how to define the term of GEC and how summarize the characteristics, component factors and motive power of GEC, are the focus and challenge of this study.
As to evaluation methodology, competitiveness research can't be done in separation with evaluation, which requires construction of scientific and objective evaluation model. Any evaluation model and method shows certain degree of subjectivity and orientation, and the contents reflected by such subjectivity and orientation might have certain guiding effect on the development and formation of the evaluated target. GEC evaluation model not only borrows and applies the mainstream methodology for international competitiveness study, but also shows unique features related to the characteristics of GEC; it must be able to objectively evaluate the GEC of all countries and reflect the internal mechanism and key points of GEC;

**Figure 4-1 GEC Research Technical Roadmap**

As to evaluation methodology, competitiveness research can't be done in separation with evaluation, which requires construction of scientific and objective evaluation model. Any evaluation model and method shows certain degree of subjectivity and orientation, and the contents reflected by such subjectivity and orientation might have certain guiding effect on the development and formation of the evaluated target. GEC evaluation model not only borrows and applies the mainstream methodology for international competitiveness study, but also shows unique features related to the characteristics of GEC; it must be able to objectively evaluate the GEC of all countries and reflect the internal mechanism and key points of GEC;
the evaluation results should also adequately reflect the philosophy behind the research, which is good to the course of global environmental protection and development of ecological economy and good to the realization of global sustainable development. The evaluation model mainly includes two parts, factor model and indicator system; the former uses quantitative analysis to conduct empirical test on the factors influencing GEC based on the connotations and characteristics of GEC, providing reference to analysis on the driving force of GEC, as the foundation of the GEC evaluation indicator system. The indicator system is the basis of competitiveness evaluation and construction of an indicator system that scientifically and objectively reflects the connotations of GEC is a very important part of GEC research. Selection of the indicators is not random and must follow definite principles; they are screened out using hierarchical model and weighted according to certain methods after careful investigation. In terms of evaluation methodology, the most mature evaluation technology in competitiveness research is adopted to conduct comprehensive evaluation on the GEC of all countries; evaluation results are also thoroughly interpreted and analyzed, and compared horizontally and vertically. Also under analysis are the comparative advantage and history of each country, the causes for such advantage or disadvantage, and the barriers of enhancing competitiveness. These analyses are not only aiming at evaluation of history and the present, but also the intrinsic factors that influence competitiveness. Judgment and prediction of the trend of competitiveness development is likewise done.

As for application of the evaluation results, focus is put on the integration of theory and practice. Evaluation results are the objective reflections of things and therefore should be used to better guide the development of the things. Of course, evaluation itself is not the purpose, but an instrument; evaluation results are neither simply rankings nor can be more visualized scores to give a better image of GEC. On the one hand, horizontal and vertical comparison of GEC may found out the advantages and disadvantages of all countries, so as to summarize the basic features and trend of development of GEC; thus the key indicators that constrain and influence the GEC of all countries, the weak link and its root, as well as the trends of GEC can all be found out. With these findings, relevant countermeasures can be proposed to help the enhancement of GEC. On the other hand, through GEC evaluation and analysis, it will be good to raise people's awareness of the importance of environmental protection and ecological economic development; awareness of enhancing GEC will be converted into feasible actions to make new contributions to the global sustainable development.

4.2 GEC Indicators Selection and Data Source

4.2.1 Selection of Indicators

Owing to the different understanding of GEC, the designed factor module may be very different, and so are the way to construct the index system and the method to select the indicators; therefore the final evaluation results would be widely divergent. Index system is the core of evaluation and the carrier of
evaluation procedures and results; whether or not a complete and objectively applicable index system can be constructed is the key to successful evaluation. First, it is very important to make the process of construction always surround the connotations and definition of GEC. Design of factor module and verification of it are also necessary, because these help to define the scope for selecting indicators and are also the reference for optimization of the index system. Secondly, there must be principles followed during construction of the index system as criteria of screening; only indicators screened via the principles can be included by the system. Finally, the system layer, factor layer and foundation layer are designed for the index system and each indicator is selected with breaking down of the layers and after several rounds of expert discussions and the final complete GEC evaluation index system is confirmed under repeated consideration. The confirmed index system is composed of 1 index, 5 Sub-index, 16 Pillars and 60 Individual indicators; each of the individual indicators is objective indicator carrying statistical data, which avoids the impact of uncertain and discrete subjective indicators on the impartiality of evaluation results.

4.2.2 Data Collection, Statistics and Calculation

Data are the basic elements of GEC evaluation; the authenticity of data directly influences the quality of evaluation results; therefore, source of data is of vital importance to evaluation results. Although the United Nations has unified the System of National Accounting (SNA) as a reference to all countries, as the countries have different state system and at different stage of development, there will be distinct differences while doing national economic accounting, especially in terms of scope of statistics, statistical range and statistical time period, which severely influences the comparability of even the same indicator in different countries.

In 1993, the United Nations formally released the System of Integrated Environment and Economic Accounting, which is featured in taking SNA as the basis to build satellite accounting covering various natural resources and environmental ecological fields and which connects the accounting of natural resources and environment with the traditional national accounting. This system added large number of estimation methods about resource consumption and reduction and environmental degradation, accompanied with enormous indicators about resources and environment. But, as the theory about resource environment accounting is not mature, practice in this area shows many problems and weaknesses; consequently, many countries failed to establish a complete accounting system, either with incomplete indicators, or inaccurate.

These problems make the selection of indicators and collection of data for this study more difficult, which actually become a bottleneck of GEC evaluation and research. In order to guarantee objectiveness and impartiality of the data source, here are the principles to be followed during selection of indicator and collection of data: 1. Better use a less number of indicators as possible, trying to select the typical indicators that can reflect the influence on GEC in certain aspect and avoiding excessive influence of the indicators on data collection; 2. Select general indicators, or the universally recognized and frequently used indicators in related researches, avoiding using obscure indicators with unclear definition or ambiguity in meaning; 3. Collect data only from international organization sources such as the UN and World Bank to guarantee the
uniform scope of statistics and comparability, statistical yearbook of the countries as the alternative source of missing data. Description of the indicators and source of the data are given in Appendix I. The sources listed in the tables means the key channel of data collection, mainly the UN, World Bank and International Energy Agency that have provided the majority of data for the countries; but many indicators lack data for certain countries, and these are obtained from the statistical yearbook or government sector official website. As these sources are in great number, details are omitted for convenience.
Appendix I

Indicators in Foundation Layer and Description

1 Resource Environmental Competitiveness (REC)

1.1 Land resource

Description: Land resource refers to the land has been used or can be used by the human being in the foreseeable future. It is the basic means of production and labor objects, and it is the basic place to the society. It reflects the capability, which the resources support the economical production.

Description: It reflects the usage of land resource and the capacity of land resource to be exploited in economic production.

1.1.1 Land area per capita

Direction: Positive

Description: Land area per capita= Land area/ total population.

Unit: square kilometers/ ten thousands

Rationale: Land is the basically material of the national actives, existence and development. And it’s the carrier place of the country’s resources. Land area per capita reflects the relative abundance of the country’s land resources.

Source: http://data.worldbank.org/indicator

1.1.2 Percentage of arable land to total land area

Direction: Positive

Description: Percentage of arable land to total land area = Arable land area / total land area×100%.

Unit: %.

Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.

Rationale: Arable land is the core part of the land resources, and it’s also the most important means of agricultural production. Arable land of the land area reflects the ownership of the land resources can be used for in agricultural production in a country.

Source: http://data.worldbank.org/indicator

1.1.3 Arable land per capita

Direction: Positive

Description: Arable land per capita = Arable land area / total population.

Unit: Hectare.

Population is defined by the conventional Description. It includes all residents, except the refugees in the country of refuge. Generally, the refugees are considered part of the population of their native country.

Rationale: Arable land per capita reflects the situation of the country's arable land relative abundance.

Source: http://data.worldbank.org/indicator

1.2 Water resource

Description: Water resource is an essential material to human being and all living. And it’s the key resources to the industrial and agricultural production, economic development and environmental improvement. The storage and distribution of water resource is an important content of resources and environment competitiveness.
**Rationale:** The index can reflect the guarantee degree of a country’s water resource on the social life and economic production.

### 1.2.1 Surface water
**Direction:** Positive
**Description:** Surface water = Surface water produced internally + Surface water entering and bordering.
**Unit:** billion cubic meters.
Surface water is water in a river, lake, fresh water wetland, or glaciers and ice sheets.
**Rationale:** Surface water is the most important water sources of human being, and it is an important part of water resources to a countries. The abundant degree can reflect the competitiveness of a country's water resources.

### 1.2.2 Annual precipitation
**Direction:** Positive
**Description:** Annual precipitation = precipitation (mm/year) / 1000000) × land area of the country (1000 ha) × 10.
**Unit:** billion cubic meters.
It refers to the quantity of water deposited, in a year, that no leakage, no loss, no evaporation.
**Rationale:** Precipitation is the main sources of fresh water resources of a country. It reflects the renewal and supplement of freshwater resources in the country.

### 1.2.3 Groundwater
**Direction:** Positive
**Description:** Groundwater = Groundwater produced internally + Groundwater entering the country.
**Unit:** billion cubic meters.
Groundwater refers to the country’s natural groundwater volume.
**Rationale:** Ground water is an important part of the available freshwater resources; the abundant degree can reflect the competitiveness of the country's water resources.

### 1.2.4 Total internal renewable water resources
**Direction:** Positive
**Description:** Renewable internal freshwater resources flows refer to internal renewable resources (internal river flows and groundwater from rainfall) in the country.
**Unit:** billion cubic meters.
**Rationale:** It reflects the country's renewable capability of freshwater resources.

### 1.3 Forest resource
**Description:** Forest can regulate the climate effectively, and conservation the soil. It can purify the air, eliminate the noise also. It is a kind of intangible resource. It is the place for forest
biological diversity. So it is an important content of resources and environment competitiveness.

**Rationale:** Forest resources can reflect the abundance levels of a country’s forest resources and biological resources, and the environmental self-purification ability.

### 1.3.1 Growing stock in forest and other wooded land

**Direction:** Positive

**Description:** Growing stock refers to volume over bark of all living trees. Volume over bark of all living trees more than \( \times \) cm in diameter at breast height (or above buttress if these are higher).

Includes the stem from ground level or stump height up to a top diameter of Y cm, and may also include branches to a minimum diameter of W cm.

**Unit:** million cubic meters.

**Rationale:** It is the basic index to reflect forest resources total scale and level, and the forest ecological environment of a country.

**Source:** http://www.fao.org/forestry/publications/zh

### 1.3.2 Proportion of land area covered by forest

**Direction:** Positive

**Description:** Proportion of land area covered by forest = forest area / land area.

**Unit:** %.

Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.

**Rationale:** Proportion of land area covered by forest reflects the abundance level of forest resources, and the country’s efforts to achieve green.

**Source:** http://data.worldbank.org/indicator

### 1.3.3 Forest area per capita

**Direction:** Positive

**Description:** Forest area per capita = forest area / total population.

**Unit:** square kilometer.

**Rationale:** It reflects the forest resources possession per capita. It reflects the relative abundance degree of forest resources to the country.

**Source:** http://data.worldbank.org/indicator

### 1.4 Energy resource

**Description:** Energy is the important elements of economic production, because it can provide a large amount of energy for human being, so it is a significant element of the resource and environment competitiveness.

**Rationale:** Energy resources reflect the ability of the country to maintain the economic production.

#### 1.4.1 Fossil energy

**Direction:** Positive

**Description:** Fossil energy including coal, oil and Natural gas, the reserves refers volume to the proved reserves volume, and all converted into oil equivalents.

**Unit:** Mtoe.

The coal including Anthracite and bituminous, Sub-bituminous and lignite.
**Rationale:** Fossil energy storage quantity reflects the ability of a country relies on its own reserves energy to maintain economic production.

**Source:**
http://www.bp.com/productlanding.do?categoryId=9041910&contentId=7075397

### 1.4.2 Energy production

**Direction:** Positive

**Description:** Energy production refers to forms of primary energy--petroleum (crude oil, natural gas liquids, and oil from nonconventional sources), natural gas, solid fuels (coal, lignite, and other derived fuels), and combustible renewables and waste--and primary electricity, all converted into oil equivalents.

**Unit:** thousand toe.

**Rationale:** It reflects the primary energy production situation, and the energy produced ability to maintain the country’s economic production.

**Source:**
http://data.worldbank.org.cn/indicator/EG.EGY.PRD.TH

### 1.4.3 Proportion of combustible renewables and waste to total energy consumption

**Direction:** Positive

**Description:** Proportion of combustible renewables and waste to total energy consumption

\[
\text{Proportion} = \frac{\text{combustible renewables and waste volume} + \text{total energy consumption}}{\text{total energy consumption}}
\]

**Unit:** %.

Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy consumption.

**Rationale:** It reflects the renewable capability of the country's resources, and the level of saving the primary energy.

**Source:** http://data.worldbank.org.cn/indicator

### 1.4.4 Net energy imports of the energy consumption

**Direction:** Negative

**Description:** Net energy imports of the energy consumption = Net volume energy imports / total energy consumption.

**Unit:** %.

Net energy imports are estimated as energy consumption less production, both measured in oil equivalents. A negative value indicates that the country is a net exporter. Energy consumption refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

**Rationale:** It reflects the relationship between a country's energy consumption and reserves. The degree of net imports is high, which means the level of the country's energy consumption is higher than its energy reserves.

**Source:** http://data.worldbank.org.cn/indicator

2 Ecological Environmental Competitiveness (EEC)

### 2.1 Biodiversity
Description: Biodiversity refers to the steady ecological complex composed of various live organism (animal, plant and microorganism) incorporated in regular pattern. It reflects the abundance of biotic resources and also the intricate relations between biotic lives as well as between environments; it even reflects the degree of human influence on ecological system. The species diversity is the key part of biological diversity.

Rationale: Biodiversity is one of the important indicators of EEC. Usually, we choose the number of species interactive in the ecological system, which can reflect the biological resource ownership and has important effects on the improvement of the ecological environment.

2.1.1 Increase of threatened fish species
Direction: Negative
Description: Threatened species is the number of species classified by IUCN as threatened, vulnerable, rare, indeterminate, out of danger or less known species.
Increase of threatened fish species = threatened fish species this year — threatened fish species last year.
Unit: species
Rationale: By making a comparison between the threatened fish species in two years to reflecting the change trend of fish biodiversity. It could also reflect the threatened fish species increased impacting on the EEC

2.1.2 Increase of threatened mammal species
Direction: Negative
Description: Threatened species is the number of species classified by IUCN as threatened, vulnerable, rare, indeterminate, out of danger or less known species.
Increase of threatened mammal species = threatened mammal species this year — threatened mammal species last year.
Unit: species
Rationale: By making a comparison between the threatened mammal species in two years to reflecting the change trend of mammal biodiversity. It could also reflect the threatened mammal species increased impacting on the EEC.
Source: http://data.worldbank.org/indicator

2.1.3 Increase of threatened plant species
Direction: Negative
Description: Threatened species is the number of species classified by IUCN as threatened, vulnerable, rare, indeterminate, out of danger or less known species.
Increase of threatened plant species = threatened plant species this year — threatened plant species last year.
Unit: species
Rationale: By making a comparison between the threatened plant species in two years to reflecting the change trend of plant biodiversity. It could also reflect the threatened plant species increased impacting on the EEC
Source: http://data.worldbank.org/indicator/EN.HPT.THRD.NO/countries
2.1.4 GEF benefits index for biodiversity

**Direction:** Positive

**Description:** GEF benefits index for biodiversity is a composite index of relative biodiversity potential for each country based on the species represented in each country, their threat status, and the diversity of habitat types in each country. It has many methods to figure out the diversity index, like Simpson’s diversity index, Shannon-weiner index. The index has been normalized so that values run from 0 (no biodiversity potential) to 100 (maximum biodiversity potential).

**Rationale:** GEF benefits index for biodiversity can reflect the level of diversity

**Source:**
http://data.worldbank.org.cn/indicator/ER.BDV.TO TL.XQ/countries

2.2 Ecological Safeguard

**Description:** Ecological safeguard reflects the effects of ecological recovery and reconstruction in a region, usually we use the area of the nature preserve to reflect it; it has big impact on ecological environmental competitiveness.

**Rationale:** By using the protected areas, it can reflect the influence degree of ecological protection policy initiatives on EEC.

2.2.1 Terrestrial protected areas

**Direction:** Positive

**Description:** Establishing nature reserves is the most important, economical and effective measures to protect the ecological environment, biological diversity and natural resources. Reserved by law or other effective means of land and related plants and historical and cultural characteristics in order to protect part or all of the enclosed environment. Terrestrial protected areas (% of total territorial area) = Terrestrial protected areas / total area of the territory.

**Unit:** %

**Rationale:** It not only reflect the ecosystem service value of preventive use, but also reflect the guarantee ability for sustainable utilization of vulnerable species and long-term stable development. It plays an important role in improving EEC.

**Source:**

2.2.2 Marine protected areas

**Direction:** Positive

**Description:** Marine protected areas are areas of intertidal or subtidal terrain--and overlying water and associated flora and fauna and historical and cultural features--that have been reserved by law or other effective means to protect part or all of the enclosed environment.

Marine protected areas (% of territorial waters) = Marine protected areas / territorial waters areas

**Unit:** %

**Rationale:** It reflects a country or region to protect the marine environment and natural resources, in accordance with the law to a certain area including the protection of objects, the coast, estuary, wetland, islands or waters with special protection and management area. It plays an important role in improving the EEC.
Source: UN-Environment Statistics Database; http://data.worldbank.org/indicator/ER.PTD.TOTL.ZS

2.3 Air quality

Description: Air quality reflects the extent of air pollution, which is based on the concentration of pollutants in the air to determine the level of air quality. The main sources of air pollutants including dust, total suspended particles, Inhalable particles (PM10), particulate matter (PM2.5), nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone and volatile organic compounds.

Rationale: Air pollution is a complex phenomenon, in a specific time and place, the air pollutant concentration is affected by many factors, including vehicle, ship, aircraft exhaust, industrial production emissions, residents living and heating, waste incineration, development density, city land topography and weather. with this index, it can affect the degree of air pollution on the ECC.

2.3.1 Inhalable particles matter (PM10)

Direction: Negative

Description: Inhalable particles matter (PM10) can stay in ambient air for a long time which has great influence on human health and atmospheric visibility. Estimated value represents the annual average exposure level of outdoor particles by common urban residents. It can use the LD-5 laser to test the PM10.

Unit: ug/M3

Rationale: It can reflect the influence of inhalable particulate matter on human disease, air visibility and health and growth of the plant. It is an important index to measure the air quality, which can reflect the degree of influence on the ECC.

Source: http://data.worldbank.org/indicator

2.3.2 Particulate matter (PM2.5)

Direction: Negative

Description: Particulate matter (PM2.5) refers to the diameter of particles in the atmosphere is less than or equal to 2.5 ug. It mainly comes from the residues of daily power, industrial production process, car emissions after combustion and emissions, mostly contain heavy metals and other toxic substances.

It can use the LD-5 laser to test the PM2.5.

Unit: 10 ug/m3

Rationale: PM2.5 has an important influence on air quality and visibility, it contains large amounts of toxic, harmful substances, therefore, it has great influence on human health and atmosphere quality. It is an important cause of air pollution, so it can use to reflect the particles impact on the ecological environment competitiveness.

Source: NASA Goddard Data and Applications Center; NASA Socioeconomic Data and Applications Center hosted by CIESIN at Columbia University

2.3.3 Index of Indoor air pollution

Direction: Negative

Description: Indoor air pollution is harmful chemical factor, physical factor and (or) biological factor entering into the indoor air and has reached directly or indirectly, short-term or long-term to the body and mind health.

Index of indoor air pollution is a form which it
changed several indoor air pollutions into one. The higher of the index, the more serious in pollution, the more obvious effects on human health.

**Unit:** %

**Rationale:** People usually spend more than 80% of the time in indoors. It reflects all kinds of harmful substances such as formaldehyde, benzene, ammonia, radon and radioactive impact on human health, this index can reflect the extent of its influence on a country or a region’s ECC.

**Source:** WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation

### 2.3.4 Nitrogen oxides emission

**Direction:** Negative

**Description:** Common nitrogen oxides include nitrogen monoxide (NO, colorless), nitrogen dioxide (NO2, reddish brown), laughing gas (N2O) and dinitrogen pentoxide (N2O5). Nitrogen oxides discharged due to human activities mostly come from the combustion process of fossil fuel, such as the combustion process in car, airplane, internal combustion engine and commercial-size kiln, and particularly from production and the process of using nitric acid, such as nitrogen fertilizer factory, organic intermediate factory, and nonferrous and ferrous metal smelters.

**Unit:** Tons of carbon dioxide equivalent

**Rationale:** Nitrogen oxides influence human health by respiratory tract invasion. It is not only one of the main factors in the air quality, but also one of the air pollutants which can be used to reflect the nitrogen oxide content effects on the ECC.

**Source:** http://unstats.un.org/

### 2.3.5 Sulfur dioxide emission

**Direction:** Negative

**Description:** As coal and petroleum normally contain sulfur compounds, they produce sulfur dioxide while burning, mainly the sulfur dioxide produced during industrial process.

We usually use the Material balance method to count it.

**Unit:** kg

**Rationale:** Sulfur dioxide will produce industrial smoke, which can stimulate the human respiratory system. Therefore, it can reflect the degree of influence on the ECC.

**Source:** http://unstats.un.org/

Smith et al., 2001; World Development Indicators; CIA Factbook

### 3 Environmental Carrying Competitiveness (ECC)

#### 3.1 Agricultural Carrying

**Description:** Agriculture is the basic source of food and other subsistence. It inevitably involves the exploitation and protection of land resources, water source. Agricultural carrying is an important part of the environmental bearing capacity and has a direct influence on it.

**Rationale:** It reflects the influence of agricultural production on the vegetation, soil and water and so on, and also reflects the influence on the environmental carrying competitiveness.

#### 3.1.1 Cereal yield per unit of arable land

**Direction:** Positive
**Description:** Cereal yield per unit of arable land = Cereal yield / arable land area.

**Unit:** kg/hectare.

Cereal yield includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals relate to crops harvested for dry grain only. Cereal crops harvested for hay or harvested green for food, feed, or silage and those used for grazing are excluded.

**Rationale:** This indicator reflects the circumstances to maintain the soil fertility, and the influence of farming on the ecological environment.

**Source:** http://data.worldbank.org/indicator

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**3.1.2 Fertilizer consumption per unit of arable land**

**Direction:** Negative

**Description:** Fertilizer consumption per unit of arable land = Fertilizer consumption / arable land area.

**Unit:** kg/hectare.

Fertilizer products cover nitrogenous, potash, and phosphate fertilizers (including ground rock phosphate). Traditional nutrients-animal and plant manures-are not included.

**Rationale:** In the process of agricultural production, fertilizer use will be a great impact on arable soil, thereby affecting the ecological environment. This indicator, which measures the fertilizer usage per unit of arable land, reflects the influence of fertilizer usage on soil quality and the environmental bearing capacity.

**Source:** http://data.worldbank.org/indicator ; http://www.nationmaster.com

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**3.1.3 Annual freshwater withdrawals for agriculture per unit of arable land**

**Direction:** Negative

**Description:** Annual freshwater withdrawals for agriculture per unit of arable land = Annual freshwater withdrawals for agriculture ÷ arable land area.

**Unit:** cubic meters/hectare.

Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source.

Withdrawals for agriculture are total withdrawals for irrigation and livestock production.

**Rationale:** In the agricultural production process, the use of fresh water will directly affect the quality of the environment. This indicator, which measures the freshwater withdrawals per unit of arable land, reflects the utilization of freshwater resources in the agricultural production process and also reflects the impact on the environment.

**Source:** http://data.worldbank.org/indicator

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**3.2 Industrial Carrying**

**Description:** Industrial production is the most important human activity and the main source of consuming resource and environment. Industrial bearer is an important part of the environmental carrying capacity and produces a great influence on it.

**Rationale:** It reflects the resource consumption of industrial production and its impact on air quality and environmental carrying competitiveness.
3.2.1 Exports as a percentage of GDP

**Direction:** Negative

**Description:** Exports as a percentage of GDP = export of goods / GDP × 100%.

**Unit:** %.

**Rationale:** The industrial products are the main export goods and consumes large amount of energy and resource. This indicator reflects the resources consumption of the industrial production and the impact on the environmental bearing capacity.

**Source:** UN-Commodity Trade Statistics Database; http://www.fmprc.gov.cn

3.2.2 Electric power consumption per unit of value added of industry

**Direction:** Negative

**Description:** Electric power consumption per unit of value added of industry = Electric power consumption / value added of industry

**Unit:** kWh/ U.S. dollar.

Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.

**Rationale:** The industrial production consumes a lot of electric power, in essence, that it consumes a lot of energy and will produce a great impact on the environment. This indicator reflects the utilizing efficiency of electric power in the industrial production process and the impact on the natural environment.

**Source:** http://data.worldbank.org/indicator

3.2.3 SO2 emissions per unit of value added of industry

**Direction:** Negative

**Description:** SO2 emissions per unit of value added of industry = SO2 emissions / value added of industry

**Unit:** kg/ U.S. dollar.

**Rationale:** In the industrial production process, it is inevitable to emit some pollutant gases. And the sulfur dioxide is an important pollution gas, causing great harm to the environment. This indicator reflects the emissions intensity of SO2 in the industrial production process, and further reflects the influence of industrial industry on the environment.

**Source:** http://unstats.un.org/; CIA Factbook

3.2.4 Annual freshwater withdrawals for industry per value added of industry

**Direction:** Negative

**Description:** Annual freshwater withdrawals for industry per value added of industry = Annual freshwater withdrawals for industry ÷ value added of industry

**Unit:** cubic meters/ U.S. dollar.

Freshwater withdrawals for industry are total withdrawals for direct industrial use (including withdrawals for cooling thermoelectric plants).

**Rationale:** The industrial production will consume a large amount of freshwater resources, and thus produce a great impact on the natural environment. This indicator reflects the utilization of freshwater resources in the industrial production process, and also reflects the impact on the environment.

**Source:** http://data.worldbank.org/indicator
3.3 Energy consumption

Description: Currently, the countries need to consume large amounts of energy, mainly fossil energy. It causes great pressure on the environment and has an important influence on the environmental bearing capacity.

Rationale: It reflects the influence of human production and life on the energy and environment, and further reflects the impact on the environmental bearing competitiveness.

3.3.1 Energy consumption per unit of land area

Direction: Negative

Description: Energy consumption per unit of land area = Energy consumption / land area.

Unit: Mtoe/square km.

Energy consumption refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

Rationale: This indicator reflects the country's bearing capacity on the energy consumption. It also reflects the influence of energy consumption on the environmental bearing competitiveness.

Source: IEA:<2012 Key World Energy Statistics>
http://www.tititudorancea.com

3.3.2 Ratio of clean energy consumption

Direction: Positive

Description: Ratio of clean energy consumption = clean energy consumption / energy consumption ×100%.

Unit: %.

Clean energy refers to the non-carbohydrate energy sources which do not produce carbon dioxide in the generation process, including hydro, nuclear, geothermal and solar energy.

Rationale: Different types of energy have different effects on the environment. The clean energy is clean and will not produce pressures on the ecological environment. This indicator measures the country's energy consumption structure, and reflects the impact on the environmental bearing capacity.

Source: IEA:<2012 Key World Energy Statistics>
http://www.data.worldbank.org/indicator

3.3.3 Elasticity of energy consumption

Direction: Negative

Description: Elasticity of energy consumption = growth rate of energy consumption / growth rate of GDP.

Rationale: The countries have different energy consumption demands because of the different economic developments. This indicator reflects each country's demand for energy consumption and its impact on environmental bearing capacity.

Source: IEA:<2012 Key World Energy Statistics>
http://data.worldbank.org/indicator

3.3.4 Elasticity of electric power consumption

Direction: Negative

Description: Elasticity of electric power consumption = growth rate of electric power consumption / growth rate of GDP.

Rationale: The countries have different electric power consumption demands because of the
different economic developments. This indicator reflects each country’s demand for electric power consumption and its impact on environmental bearing capacity.

**Source:** http://data.worldbank.org/indicator

### 3.4 Greenhouse Gases

**Description:** Greenhouse Gases has an important impact on human activities and may even lead to ecological disaster. Its impact on the environment bearing capacity can not be ignored.

**Rationale:** The climate change reflects the impact of human activities on the natural environment and the environmental bearing competitiveness.

#### 3.4.1 Growth rate of CO2 emissions

**Direction:** Negative

**Description:** Growth rate of CO2 emissions = CO2 emissions / CO2 emissions (-1) ×100%.

**Unit:** %.

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

**Rationale:** Carbon dioxide is the most important greenhouse gas. The change of carbon dioxide emissions directly reflects the influence of human activities on climate change. This indicator reflects the change of the bearing capacity on the carbon dioxide emissions.

**Source:** IEA:<2012 Key World Energy Statistics>

#### 3.4.2 Growth rate of Methane emissions

**Direction:** Negative

**Description:** Growth rate of Methane emissions = Methane emissions/ Methane emissions(-1)×100%.

**Unit:** %.

Methane emissions are those stemming from human activities such as agriculture and from industrial methane production.

**Rationale:** Methane is an important greenhouse gas. The change of Methane emissions also reflects the influence of human activities on climate change. This indicator reflects the change of the bearing capacity on the methane emissions.

**Source:** UN-Greenhouse Gas Inventory Data

#### 3.4.3 CO2 emissions per unit of land area

**Direction:** Negative

**Description:** CO2 emissions per unit of land area = CO2 emissions / land area.

**Unit:** Million tons/square km

**Rationale:** This indicator reflects the country’s bearing capacity on the carbon dioxide emissions. It also reflects the influence of carbon dioxide emissions on the environmental bearing competitiveness.

**Source:** IEA:<2012 Key World Energy Statistics>

#### 3.4.4 CO2 emissions per unit of energy consumption

**Direction:** Negative

**Description:** CO2 emissions per unit of energy consumption=CO2 emissions/energy consumption.

**Unit:** Million tons/Mtoe

**Rationale:** The carbon dioxide emissions mainly come from the energy consumption. This indicator measures the carbon dioxide emission intensity of the energy consumption and reflects the influence
of energy consumption on climate change. 

**Source:** IEA:<2012 Key World Energy Statistics>

4 Environmental Management Competitiveness (EMC)  

4.1 Environmental Governance  

**Description:** Environmental governance refers to the human activities, in order to achieve the desired environmental objectives, of governing the natural environment through the institution, control, supervision and so on. The effective environmental governance can reduce the negative impact of human activities on the environment, and improve the environmental conditions making the environmental systems working well.  

**Rationale:** This indicator measures the country's governance and supervision level on the natural environment. It reflects the country’s positive influence on the natural environment and the efforts to protect and improve the environment.  

4.1.1 Agricultural chemicals regulation  

**Direction:** positive  

**Description:** It refers to the regulation implement and supervision on the use of agricultural chemicals.  

**Rationale:** The better or the worse of pesticide regulation in agricultural production can directly reflect the impact of pesticide in water, atmosphere, soil, vegetation and related biological ecological environment.  

**Source:** UNEP-Chemicals; http://chartsbin.com/view/1473

4.1.2 Percentage of the rural population with access to an improved water source to rural population  

**Direction:** positive  

**Description:** Percentage of the rural population with access to an improved water source to rural population= rural population with access to an improved water source / rural population×100%.  

**Unit:** %.  

Access to an improved water source refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs.  

**Rationale:** The governance of rural water is an important part of environmental management and protection. This indicator reflects the basic situation of rural water sources, and also shows the protection and improvement of water quality of rural water source.  

**Source:** http://data.worldbank.org/indicator  

4.1.3 Percentage of the urban population with access to an improved water source to urban population  

**Direction:** positive  

**Description:** Percentage of the urban population with access to an improved water source to urban population= urban population with access to an improved water source / urban population×100%.  

**Unit:** %.  

**Rationale:** The governance of urban water is an important part of environmental management and
protection. This indicator reflects the basic situation of urban water sources, and also shows the protection and improvement of water quality of urban water source.

**Source:** http://data.worldbank.org/indicator

### 4.2 Ecological Protection

**Description:** Ecological protection reflects the effects of ecological recovery and reconstruction in a region; it has big impact on ecological environmental competitiveness.

**Rationale:** It can reflect the influence degree of ecological protection policy initiatives on EEC through the efforts to protect and improve the ecological environment.

#### 4.2.1 Biome protect

**Direction:** Positive

**Description:** Biological communities mean all kinds of creatures which live in certain natural areas have direct or indirect relation between them. Biome protect=Biome protect species/Biome species

**Unit:** %

**Rationale:** It not only reflects the community species diversity, community growth form, the number of different species of dominant species, the relative proportion of features, but also reflects the degree of influence on the EEC.

**Source:** UNEP World Conservation Monitoring Centre; World Wildlife Fund USA

#### 4.2.2 Area of plantation and afforestation

**Direction:** positive

**Description:** Planted forests are composed of trees established through planting and/or through deliberate seeding of native or introduced species.

**Rationale:** This indicator of planted forest can show the effort to fix a large amount of carbon dioxide and other greenhouse gases, to slow global warming, to improve the environment

**Source:** http://www.fao.org/forestry/fra/fra2010/en/

#### 4.2.3 Overfishing of fishing resources

**Direction:** Negative

**Description:** Catching and fishing from offshore fishery resources influence the normal reproduction of fish stock and cause decrease of species and reduction in quantity.

**Rationale:** If the management of overfishing on fishery resources is not enough, it will destroy the marine ecological environment, thus it will seriously affect the sustainable development of marine fishery resources.

**Source:** Sea Around Us Project, Fisheries Centre, University of British Columbia

### 4.3 Resource Utilization resources

**Description:** Resource utilization refers to the exploitation, allocation and use of natural resources by humans. It is an important part of environmental management to rationally and effectively optimize the allocation of resources and improve the utilization efficiency of resource, and it produces an important impact on environmental management competitiveness.

**Rationale:** Modern economy must consume the natural resources. And it is inevitable to face the over-exploitation of resources, environmental pollution and damage. This indicator reflects the
country's utilization states of various resources and the influence of resource utilization on resources and environment.

4.3.1 Utilization rate of water

**Direction:** negative

**Description:** It refers to the ratio of water consumption to the total water resources in the drainage basin or region.

**Unit:** %.

**Rationale:** The indicator is to test the country’s use of water resources, reflecting the degree of exploitation and utilization of water resources. The international community generally believes that the exploitation and utilization of a river can not exceed 40% of its water resources.

**Source:** http://unstats.un.org/

4.3.2 Percentage of total internal renewable water resources to total water resources

**Direction:** Positive

**Description:** Percentage of total internal renewable water resources to total water resources = total internal renewable water resources / total water resources×100%.

**Unit:** %.

**Rationale:** This indicator reflects the renewable capability of freshwater resources in the process of using water resource, and also reflects the effect of wastewater treatment and water recycling.


4.3.3 Percentage of agricultural land to total land area

**Direction:** Positive

**Description:** Percentage of agricultural land to total land area = agricultural land area / total land area×100%.

**Unit:** %.

**Rationale:** Agricultural land refers to the land that is arable, under permanent crops, and under permanent pastures.

**Source:** http://data.worldbank.org/indicator

4.3.4 Percentage of fossil fuel energy consumption to total energy consumption

**Direction:** Negative

**Description:** Percentage of fossil fuel energy consumption to total energy consumption = fossil fuel energy consumption / total energy consumption×100%.

**Unit:** %.

**Rationale:** Fossil fuel comprises coal, oil, petroleum, and natural gas products.

**Source:** Fossil fuel is the primary energy. It supports the country's economic and social development, but it causes a great impact on the environment. This indicator reflects the utilization state of fossil fuel energy and its impact on the
environment.

**Source:** http://data.worldbank.org/indicator

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5 Environmental Harmony Competitiveness (EHC).

5.1 Population and Environment

**Description:** There is interdependence between population and environment influence each other close relationships.

**Rationale:** Reflect the degree of coordinated development of population and the environment.

5.1.1 Improved sanitation facilities (% of population with access)

**Direction:** Positive

**Description:** Improved sanitation facilities (% of population with access)= the population access to improved sanitation facilities / mid-year population

**Unit:** %.

Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Improved facilities range from simple but protected pit latrines to flush toilets with a sewerage connection.

**Rationale:** Improved sanitation facility is one of the important contents to protect basic survival and development of members of society. It is not only able to protect human health, but also to protect the ecological environment. Improved sanitation facilities (% of population with access) reflect the coordinated development degree between population and the environment.

**Source:** World Health Organization and UNICEF Joint Monitoring Programme (JMP) (http://www.wssinfo.org/)

5.1.2 Motor vehicles (per 1,000 people)

**Direction:** Negative

**Description:** Motor vehicles (per 1,000 people)= Motor vehicles /mid-year population

**Unit:** vehicles per 1,000 people.

Motor vehicles include cars, buses, and freight vehicles but do not include two-wheelers. Population refers to midyear population in the year for which data are available.

**Rationale:** Automobile exhaust emissions are important sources of carbon emissions, causing serious air pollution, endangering human health and environmental effects. With population expansion and the increase in car ownership, car and environment, energy and other related contradictions have become increasingly prominent. Motor vehicles (per 1,000 people) can be a reflection of the population impact on the environment.

**Source:** http://data.worldbank.org/indicator

5.1.3 Renewable internal freshwater resources per capita

**Direction:** Positive

**Description:** Renewable internal freshwater resources per capita= Renewable internal freshwater resources / mid-year population

**Unit:** cubic meters per capita

Average renewable internal freshwater resources calculated by mid-year population. Renewable internal freshwater resources flows refer to internal
renewable resources (internal river flows and groundwater from rainfall) in the country.

**Rationale:** Fresh water as a renewable resource, mainly recharged by atmospheric precipitation. With the increase in population and economic development, freshwater resources are becoming scarce. Economical use of freshwater resources, reduce pollution and improve renewable freshwater resources per capita ownership for achieving the coordinated development of population and the environment has important significance.

**Source:** FAO, Agriculture and Water Information System (AQUASTAT)

### 5.1.4 SO2 emissions (metric tons per capita)

**Direction:** Negative

**Description:** SO2 emissions (metric tons per capita)= SO2 emissions /mid-year population

**Unit:** metric tons per capita

Average SO2 emissions calculated by mid-year population. Sulfur dioxide emissions are mainly industrial enterprises in the fuel combustion and production processes in the atmosphere of total sulfur dioxide.

**Rationale:** Sulfur dioxide is one of the main pollutants in the atmosphere. It is an important indicator to measure whether there has been an atmospheric pollution. Sulfur dioxide emissions not only damage to human health, but also to the ecosystems and agriculture, forestry, aquatic resources. Sulfur dioxide emissions per capita reflect the harmful levels to human and ecological environment.

**Source:** http://unstats.un.org/; CIA Factbook

### 5.1.5 CO2 emissions (metric tons per capita)

**Direction:** Negative

**Description:** CO2 emissions (metric tons per capita)= CO2 emissions /mid-year population

**Unit:** metric tons per capita

Average carbon dioxide emissions calculated by mid-year population. Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

**Rationale:** Carbon dioxide accounted for 50% of the effect of global warming. The total population has an incremental effect on carbon dioxide emissions, the more the population, the more energy and resource consumption, carbon dioxide emissions will be greater. CO2 emissions per capita reflect the impact of human activities on climate level. It has an important role for promoting the development of low-carbon economy.

**Source:** IEA:<2012 Key World Energy Statistics>

### 5.1.6 Energy consumption per capita

**Direction:** Negative

**Description:** Energy consumption (kg of oil equivalent per capita)= Energy consumption / mid-year population

**Unit:** kg of oil equivalent per capita

Average energy consumption calculated by mid-year population. Energy consumption refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft.
engaged in international transport.

**Rationale:** The total consumption of energy is strictly related to the volume of population of one country or area, and due to the difference of population in different countries, the indicator of total consumption of energy cannot reveal the difference of level of consumption, so the indicator of energy consumption per GDP can more accurately express the level of consumption of energy and its variation trend.

**Source:** IEA:<2012 Key World Energy Statistics>

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### 5.2 Economy and Environment

**Description:** Economy and the environment is a system of two factors. The two have the dialectic relationship of the unity of opposites.

**Rationale:** Reflect the degree of coordinated development of economy and environment.

---

#### 5.2.1 Land resource utilization efficiency

**Direction:** Positive

**Description:** Land resource utilization efficiency = GDP / Land area

**Unit:** USD / sq km

Land area per unit of GDP (PPP) is gross domestic product converted to international dollars using purchasing power parity rates.

**Rationale:** The land resource utilization efficiency can not only tell the economic discrepancy of different countries and areas, but also the degree of industrialization and pollution of one country or area, so as to reveal the coordinated development of economy and environment in different countries and areas.

**Source:** http://data.worldbank.org/indicator

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#### 5.2.2 Sulfur dioxide emissions per unit of GDP

**Direction:** Negative

**Description:** Sulfur dioxide emissions per unit of GDP = sulfur dioxide emissions / GDP

**Unit:** metric tons per $1,000 GDP

Calculated per unit of GDP by sulfur dioxide emissions. PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates.

**Rationale:** The emission of sulfur dioxide per GDP is an important indicator of the quality of economic development. By using such indicator as intensity of the emission of sulfur dioxide per GDP, we can have the idea of happiness and well-being and economic transformation and the development of human living areas of one country.

**Source:** http://unstats.un.org/; CIA Factbook

---

#### 5.2.3 Carbon dioxide emissions per unit of GDP

**Direction:** Negative

**Description:** Carbon dioxide emissions per unit of GDP = carbon dioxide emissions / GDP

**Unit:** metric tons per $1,000 GDP

Calculated per unit of GDP by carbon dioxide emissions. PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates.

**Rationale:** The emission of sulfur dioxide per GDP is an important indicator of the achievement of controlling of the emission of carbon dioxide and slowing down the climate change. The data reveal that emission of carbon dioxide increases in proportion to the GDP per capita. By using the emission of carbon dioxide per GDP, we can guide
the different countries and areas to emit less carbon dioxide while achieving the economic growth, so as to promote the sustainable development of economy, society and environment.

Source: IEA:<2012 Key World Energy Statistics>

5.2.4 Energy consumption per unit of GDP

Direction: Negative

Description: Energy consumption per unit of GDP

\[\text{GDP per unit of energy consumption} = \text{Energy consumption} / \text{GDP}\]

Unit: kg of oil equivalent per $1,000 GDP

GDP per unit of energy consumption is the PPP GDP per kilogram of oil equivalent of energy consumption. PPP GDP is gross domestic product converted to current international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as a U.S. dollar has in the United States.

Rationale: Energy consumption per unit of GDP is a main indicator that reveal the level of energy consumption and energy saving, which can also reveal energy consumption efficiency and dependence. It expresses the use of energy of one country or area, and the change of economic structure and energy using structure, which could guide one country or government to make appropriate policies to save energy.

Source: IEA:<2012 Key World Energy Statistics>
4.2.3 Data Extreme Value Analysis

Among the substantial statistical indicator data, it is inevitable to have some "noise" data (maximum or minimum value), i.e. individual datum that shows big difference from the majority of the data. Such phenomena might be the problem of the indicators due to the wide gap between themselves, or the error during the process of data collection and reorganization. Particularly under current circumstance when the resource environment statistics system is far from sound, statistical survey and method of reorganizing the data might both lead to "noise" data. The numerous indicators in GEC evaluation indicator system involve many entirely new areas, and some, including resource and environment areas, do not have well established sound statistical system; actually, some of the statistical methods are still under modification. These are all challenges for the authenticity and objectivity of the GEC indicator data. In addition, the geographical scope of evaluation covers more than 130 countries widely distributed around the globe and the national conditions in each country are varied; it is quite possible to see data error in the process of accounting. The existence of "noise" data is a negative factor for the evaluation of GEC. Especially, the evaluation adopts comprehensive weighting method, under which the comprehensive competitiveness score is obtained from the weighted score of the lower-layer indicators and the bottommost quaternary indicator scores are obtained from the non-dimensional value of evaluation samples by efficiency coefficient method; in other words, the score of single indicator will affect the total evaluation score through weighting layer by layer. If some indicator carries maximum or minimum value, the scores of the samples calculated according to the non-dimensional formula by efficiency coefficient method will be enormously different and the distribution of evaluation scores turn to be irrational, which all influences the evaluation result. In addition to analysis on the characteristics of each indicator and making judgment, it is also fully necessary to find possible extreme values of the indicator using appropriate quantitative approach and process the extreme values.

The judgment of extreme value is carries out according to the variance of data distribution. Indicator data shows certain distributional characteristics among the samples and the distance between each datum and their average value always follows certain laws and is related to the standard deviation of the sample data. Suppose data are in normal distribution, then 99.97% of the data will be distributed within the range of 3 standard deviation of the average value, i.e.:

\[
P(|(x - \bar{x})/\sigma| < 3) = 0.9997
\]

\[
\sigma = \sqrt{\sum (x - \bar{x})^2/(n-1)}
\]

\(\bar{x}\) is the average value of sample data and \(\sigma\) is the standard deviation of sample data. Of course, the actual distribution of indicators would not be strictly in normal state, but according to the Law of Large Numbers, even the indicator data is other state of distribution, such feature also exists. So, if certain sample value of the indicators goes beyond the range of 3 standard deviation of the average value, the value can be judged as the extreme value of the indicator and needs regression to within the range after treatment of re-check and revision.

4.3 GEC Indicator System Correlation Analysis

In the process of GEC evaluation, setting up the index system is a core step. In order to adequately reflect the different factors that influence environmental competitiveness, the index system becomes huge with enormous indicators and covers substantial contents. The merit of such setting is to avoid insufficiency of information because of too small number of indicator and to reflect multiple aspects of GEC. At the same time, such arrangement can prevent improper influence on the evaluation results caused by extraordinary fluctuation of individual indicator, unless the number of indicator is too small; in this way, the evaluation results will be ore stabilized and rational. But, the problem faced during construction of the comprehensive

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index system is that the indicators, more or less, shows correlation, or, different indicators containing same information; actually, during the process of evaluation, repetition of information is quite often. If the contents reflected by two indicators are similar or of the same nature, then the indicators contain repeated information; and if both of the indicators are included by the indicator system, the consequence is overlapping of indicator and information redundancy, or even contradiction. During evaluation, this part of information would be calculated doubly, which influences the precision of evaluation results. The indicators in the GEC evaluation index system cover multiple aspects including ecological environment, resource environment, environmental management, environmental carrying and environmental harmony, 5 Sub-index, 16 pillars and 60 individual indicators in total. There has been large amount of information commonly reflected by indicators, particularly those, that are related to economic and social activities, very often showing strong correlation in between. This is also bad for analysis on the driving power of competitiveness. Therefore, a correlation analysis on the indicators should be done first. When obvious correlation is diagnosed, relevant treatment is necessary to remove such correlation.

Indicator correlation analysis is a study of whether there is dependent relation between existing phenomena and discussion of the direction and degree of correlation in specific phenomena having dependent relationship; it is a kind of statistical method to study the correlativity between random variables. By the direction of changing in the two variables, correlativity includes positive correlation, negative correlation and no correlation. 1) Positive Correlation: When one variable increases or decreases, the other variable is also increasing or decreasing and the directions of changing for both variables are the same, which is called positive correlation. 2) Negative Correlation: When one variable increases or decreases, the other variable is also decreasing or increasing and the directions of changing for both variables are opposite, which is called negative correlation. 3) No Correlation: Between two variables, the change in one variable is not related to the change of the other variable; such relationship is also called zero correlation. Of course, such classification is only a simple judgment of the relationship between two variables, which is not precise. A more precise statistical indicator is needed to reflect such relationship between two variables, i.e. using a statistic to reflect the correlation between two variables. According to the type of variable data, different calculation method should be used. GEC indicator system data are continuous variable using scale and dimension of definite proportion and therefore can use "product moment method" to calculate the correlation coefficient, measuring the degree of correlation. This method uses the product of the dispersion of the two variables and the respective mean value, i.e. Pearson's formula:

\[
    r_{xy} = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}
\]

\(x\) and \(y\) are the two variables to be measured in terms of correlation coefficient. \(r_{xy}\) is the coefficient, reflecting the statistic of correlativity between \(x\) and \(y\), also called simple correlation coefficient. The sign symbol of \(r_{xy}\) determines the positive or negative correlation between \(x\) and \(y\) and the value of \(r_{xy}\) is between -1 and 1. The closer the absolute value is to 1, the higher the correlation between \(x\) and \(y\) will be; vice versa, the closer the absolute value of \(\rho_{xy}\) is to 0, the less obvious the correlation between \(x\) and \(y\) will be. There is reference standard to judge and test the correlativity, by the test statistic of:

\[
    t = \sqrt{\frac{r_{xy}^2(n-2)}{1-r_{xy}^2}} \sim t_{0.025(n-2)}
\]

Although correlativity only reflects the relevancy between two indicators, in a comprehensive indicator system, the relationship between multiple indicators is complicated, mutually influencing and interrelated.
Multiple correlation is right the study of correlativity between one variable and another set variables; it can reflect the correlation of multiple indicators. The philosophy behind this is the same as simple correlation coefficient; the larger the value, the closer relation between the variables. It is generally used in multiple regression analysis and suitable for factor analysis.

Through calculation of the correlation coefficients between each layer of indicators, the summarized results after test of significance are given in Table 4-1.

<table>
<thead>
<tr>
<th>Indicator Type</th>
<th>Number of Subordinate Indicator</th>
<th>Number of Correlation Coefficient</th>
<th>Max. Value of Correlation Coefficient</th>
<th>Significance Tests of Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Resources Pillar</td>
<td>3</td>
<td>3</td>
<td>0.407</td>
<td>2</td>
</tr>
<tr>
<td>Water Resources Pillar</td>
<td>4</td>
<td>6</td>
<td>0.858</td>
<td>6</td>
</tr>
<tr>
<td>Forest Resources Pillar</td>
<td>3</td>
<td>3</td>
<td>0.454</td>
<td>3</td>
</tr>
<tr>
<td>Energy Resource Pillar</td>
<td>4</td>
<td>6</td>
<td>0.564</td>
<td>3</td>
</tr>
<tr>
<td>Biodiversity Pillar</td>
<td>4</td>
<td>6</td>
<td>0.761</td>
<td>6</td>
</tr>
<tr>
<td>Ecological Safeguard</td>
<td>2</td>
<td>1</td>
<td>0.341</td>
<td>1</td>
</tr>
<tr>
<td>Air Quality Pillar</td>
<td>5</td>
<td>10</td>
<td>0.879</td>
<td>5</td>
</tr>
<tr>
<td>Agricultural Carrying</td>
<td>3</td>
<td>3</td>
<td>0.419</td>
<td>2</td>
</tr>
<tr>
<td>Industrial Carrying Energy</td>
<td>4</td>
<td>6</td>
<td>0.516</td>
<td>1</td>
</tr>
<tr>
<td>Consumption</td>
<td></td>
<td></td>
<td>0.876</td>
<td>1</td>
</tr>
<tr>
<td>Greenhouse Gas Governance</td>
<td>4</td>
<td>6</td>
<td>0.143</td>
<td>0</td>
</tr>
<tr>
<td>Environmental Safety</td>
<td>3</td>
<td>3</td>
<td>0.542</td>
<td>2</td>
</tr>
<tr>
<td>Resource Utilization</td>
<td></td>
<td></td>
<td>0.056</td>
<td>0</td>
</tr>
<tr>
<td>Population and Environment</td>
<td>6</td>
<td>15</td>
<td>0.960</td>
<td>3</td>
</tr>
<tr>
<td>Economy and Environment</td>
<td>4</td>
<td>6</td>
<td>0.597</td>
<td>2</td>
</tr>
</tbody>
</table>

The indicator correlation statistics show that correlation between the original data of some environmental competitiveness indicators is relatively obvious and that the correlation coefficient between the 4 pillar and the subordinate individual indicators is relatively larger. More number of correlation coefficient that passes the significance test indicates that many original indicators show higher correlation. But, except that the individual indicators show certain correlation, the correlation between sub-index and between pillars are not high, which means little influence on the calculation of comprehensive evaluation score and the reliability of both scores and rankings of GEC.
Chapter 5 Overall Evaluation and Comparative Analysis on GEC

What the tide of globalization brings is unprecedented impact on humankind by global environmental problems and these problems have become the economic, political and cultural problems that restrict human existence and development. It can be said that the humankind is entering the era when the competition begins to focus on environment. This book for the first time introduces Global Environment Competitiveness (GEC) as a new way of weighing competitiveness and demonstrates a nation's environment competitiveness through five elements, ecological environment, resource environment, environment carrying, environmental management and environment harmony, in the hope of providing reference for all countries to do complete and scientific analysis on environmental situation and to propose environmental development strategy. This part selects 133 countries of the world (See Figure 5-1) as samples to analyze the distribution and rankings of global and regional environment competitiveness in 2012 so that the development changes, influencing factors and future trends of global competitiveness can be revealed, which will provide helpful reference for realization of sustainable development around the globe.

5.1 Overall Evaluation of GEC

5.1.1 GEC Evaluation Results

The research group completes the evaluation and analysis on the Global Environment Competitiveness in 2012 based on the GEC Evaluation Indicator System and mathematical model. Table 1-1 gives the environment competitiveness rankings and scores of the countries in 2012 and Figure 5-2 shows the environment competitiveness scores of the six continents of the world and the top 3 countries in each
continent.

Figure 5-2 Environment Competitiveness Scores of Six Continents and Top 3 Countries in Each Continent

5.1.2 GEC Comprehensive Ranking

As Table 5-1 shows, countries with global environment competitiveness ranking 1\textsuperscript{st}-10\textsuperscript{th} include Switzerland, Germany, Norway, New Zealand, Brazil, Japan, Costa Rica, Austria, United Kingdom and France; the 11\textsuperscript{th}-20\textsuperscript{th} rankings are Ecuador, Venezuela, RB, Slovak, Sweden, Bolivia, Honduras, Guatemala, Canada, Gabon and Colombia; the 21\textsuperscript{st}-30\textsuperscript{th} rankings are Australia, Nicaragua, Panama, Chile, Belgium, United States, Slovenia, Finland, Philippines and Denmark; and the bottom 10 countries are Kuwait, Yemen, Rep., Libya, Uzbekistan, Kazakhstan, Mauritania, Mali, Iraq, Lesotho and Niger, all listed in order of rank.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>GEC Rank</th>
<th>GEC Score</th>
<th>REC Rank</th>
<th>REC Score</th>
<th>EEC Rank</th>
<th>EEC Score</th>
<th>ECC Rank</th>
<th>ECC Score</th>
<th>EMC Rank</th>
<th>EMC Score</th>
<th>EHC Rank</th>
<th>EHC Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switzerland</td>
<td>1</td>
<td>58.7</td>
<td>63</td>
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5.1.3 Overall GEC Scores

In 2012, the highest GEC score was 58.7 points, the lowest score was 32.3 points and the average score was 49.6 points; this indicates that the overall environment competitiveness in all countries of the world is yet to be improved, as there is not a single country that scored over 60 points.

The distribution of GEC scores of the countries shows ladder pattern. Among these, 18 countries scored over 55 points; 47 countries scored between 50-55 points; 49 countries scored between 45-50 points; 13 countries scored between 40-45 points; 5 countries scored between 35-40 points; 1 country scored between 30-35 points; and no country scored below 30 points. It is obvious that most countries scored above 45 points and only a few countries obtained scores lower than 45 points. Furthermore, the standard deviation of GEC scores was as small as 4.8, which means the difference between the environment competitiveness in the countries are not large, and particularly the difference between countries with close rankings was very small.

Countries with higher scores are mainly developed countries and there are 17 developed countries among the top 30 rankings, accounting for a ratio of 56.7%, and 8 developed countries among the top 10 rankings, accounting for a ratio of 80.0%. Countries with lower scores are mostly developing countries, mainly because of the long-existing wide gap in socioeconomic development foundation, environmental protection input, environment management and environmental technology between developed and developing countries.

In order to intuitively make a comparative analysis on the environment competitiveness of the countries, the environment competitiveness scores in 2012 are presented in Figure 5-3. As the figure shows, there are 67 countries that scored higher than the average score, accounting for 50.38% of total countries. As a whole, the difference between all countries was not large, but the scores of bottom 10 countries were left far behind other countries, especially Niger ranking the last, whose score was 32.3, leaving 26.4 points of gap from the highest score and even 17.3 points of gap from the average score. Among developed countries, the highest score 58.7 goes to Switzerland, ranking the 1st place; the lowest score 44.3 goes to Qatar, ranking 118th place. Among developing countries, the highest score 57.5 goes to Brazil, ranking the 5th and the lowest score 32.3 goes to Niger, ranking the 133rd.
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<th>Score</th>
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5.2 GEC Factor Scores and Contribution Rate

Table 5-1 is the evaluation result of the sub-indexes for GEC in 2012 and shows the scores and rankings of the 5 sub-indexes.

The standard deviation of Ecological Environment Competitiveness (EEC) in 2012 is 9.3, indicating that the indicator demonstrates the largest difference between countries and it is the key factor leading to the difference in environment competitiveness among the countries. Besides, the standard deviation values of Environmental Management Competitiveness (EMC) and Environmental Harmony Competitiveness (EHC) are also as high as 9.1 and 8.9, which are also the important causes of competitiveness difference. As for the standard deviation values of Resource Environment Competitiveness (REC) and Environment Carrying Competitiveness (ECC) are relatively small. ECC’s standard deviation is the smallest, at 5.3, which means that ECC has little influence on the environment competitiveness difference between the countries. Basically, the overall environment competitiveness of the countries shows no big difference, while the major causes for competitiveness difference are reflected in EEC, EMC and EHC; of course, REC and ECC also exert certain influence, but at lesser degree. Therefore, countries with weak environment competitiveness need to especially strengthen the efforts in EEC, EMC and EHC, so as to narrow the gap between them and other countries and to significantly enhance their environmental competitiveness.

In order to better analyze sub-indexes' contribution to primary indicator, the scores of sub-indexes are multiplied by respective weights and converted to the scores reflected on primary indicator; after divided by the total score of primary indicator, the contribution rates of each sub-index can be obtained. In this way, each sub-index's contribution to the primary indicator will be straightforward, as shown in Figure 5-4.

Figure 5-4 shows that ECC made the greatest contribution to GEC, with an average contribution rate of 27.0%; EHC was the second greatest contributor, at a rate of 26.2%; the contribution rate of REC and EMC were both 19.8%; REC made the least contribution, at a rate of 7.2%. Therefore, ECC and EHC are the two indicators that deserve special attention for all countries in their process of enhancing environmental competitiveness. Of course, the effects of REC, EEC and EMC must not be neglected.
Figure 5.4 Contribution Rates of GEC Sub-indexes 2012
5.3 GEC Echelon Scores

Table 5-2 lists the average scores of the five echelons (First Echelon: countries ranking 1st-10th; Second Echelon: countries ranking 11th-30th; Third Echelon: countries ranking 31st-60th; Fourth Echelon: countries ranking 61st-100th; Fifth Echelon: countries ranking 101st-133rd) of GEC in 2012.

As shown in the table, the average environmental competitiveness scores of first, second and third echelons are close with small difference, presenting a ratio of 1.11:1.05:1. The difference between the fourth and fifth echelons and the previous three echelons are larger and the score of First Echelon is 1.33 times that of Fifth Echelon, leaving a gap of 14.1 points.

The average REC score of each echelon shows very big difference, presenting a ratio of 1.83:1.91:1.67:1.34:1.

The average EEC score of each echelon also shows big difference, presenting a ratio of 1.50:1.33:1.22:1.08:1.

The difference of average ECC scores between the echelons is slight, presenting a ratio of 1.11:1.07:1.06:1.03:1.

The average EMC score of each echelon shows big difference, presenting a ratio of 1.48:1.38:1.30:1.22:1.

The difference of average EHC scores between the echelons is small, presenting a ratio of 1.23:1.21:1.18:1.14:1.

<table>
<thead>
<tr>
<th>Table 5-2 Average Environmental Competitiveness Scores of Each Echelon 2012</th>
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<td>First Echelon</td>
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<td>Fifth Echelon</td>
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Table 5-2 and Figure 5-5 together may better describe the scores of the primary indicator and sub-indexes in each echelon and it is each to find that, except for REC, the scores of environmental competitiveness and the other 4 sub-indexes diminishes from first to fifth echelon; the REC score of each echelon is the lowest and the highest case is only 23.4 points; the difference between the EEC scores of first and fifth echelons is most distinct, while the difference of ECC scores among all echelons is the least.
5.4 Regional Analysis of GEC

5.4.1 Balance Analysis of GEC

The GEC scores and rankings of the countries obtained through non-dimensional processing with threshold method and weighted summing only reflect the status of environmental competitiveness of single country. To reflect the physical variance and overall status of the GEC in each country, GEC scores and its distribution as well as the physical difference and balance among the scores need in-depth study and analysis. Figure 5-10 shows the evaluation scores of GEC in 2012 and distribution of such scores.

It can be found from Figure 5-6 that the GEC scores of the countries are not distributed in balance, with most countries scoring 45-55 points, accounting for 72.93%; countries scoring 40-45 points account for 9.77%; countries scoring higher than 55 account for 12.78%; and countries scoring lower than 40 are few in number, accounting for 4.51%. Generally speaking, GEC evaluation scores are in symmetrical distribution, and the GEC scores demonstrate wide gap between the countries, as the lowest score 32.3 for Niger is only 55% of
that of the highest score for Switzerland, a gap of 26.4 points. It should be pointed out that the score
difference between close rankings is generally very small, and therefore the relative ranking of the indicators
is not stable.

5.4.2 Regional Evaluation and Analysis of GEC

Table 5-3 lists the average GEC and sub-index scores of the 133 countries covered by this study by six
contents of the world (Antarctica is excluded since there is no country on the continent).

According to the GEC scores of the six continents in 2012, Oceania obtained the highest GEC score, at
56.3 points; Europe, South America and North America scores were also high, all over 50 points; the lowest
score occurred to Africa, at 46.7 points. As a whole, the gap between the GEC of six continents was narrow,
showing a score ratio of 1.02:1.12:1:1.20:1.13:1.14.

Within Asia, the GEC scores of East Asia and Southeast Asia were relatively higher, at 50.8 points and
50.6 points respectively; next to them is South Asia that scored 48.0 points; Central Asia scored the lowest,
only at 42.1 points.

Within Europe, the highest GEC score went to North Europe, at 55.0 points and it is also the second
highest score among all regions in the six continents; scores of Central Europe and West Europe were also
high, all above 50 points; the score of East Europe was the lowest, at 49.0 points.

Within Africa, scores of all regions showed no big difference, all below 50 points. Central Africa's score
was the highest, at 49.1 points; next to it is East Africa, at 47.0 points; West Africa's score was the lowest.

According to the sub-index scores of the six continents in 2012, the REC, EEC and EMC scores of
Oceania were all the highest, but its ECC and EHC both ranked only the 2nd from bottom; Africa's REC,
EMC and EHC scores were all the lowest among six continents and its EEC ranked the 2nd from bottom.

With respect to REC, scores of all continents showed narrow difference, in which Oceania scored the
highest and Asia and Africa scored lower; within Asia, only Southeast Asia and South Asia scored no less
than 20 points and all other regions scored below 20, while the scores of all African regions were below 20.
Among all regions, Central Asia's score was the lowest, at 10.5 points and only 37.4% of the highest score
for Oceania.

With respect to EEC, the gap between six continents was relatively wider; Oceania obtained the highest
score of 66.6 points, while Asia scored the lowest, leaving wide gap between itself and other five continents.
Within Asia, each region scored below 50 points and South Asia scored the lowest 35.8 points. Within
Europe, regional scores showed big difference, leaving a gap of 14.4 points between the highest and the
lowest scores. Africa showed small difference in scores, with a gap of 9.0 points between the highest and the
lowest scores.

With respect to ECC, scores of six continents were relatively high, all above 60 points with small
difference, in which West Europe scored the highest 71.6 points; next to West Europe was North Europe,
scoring 71.0 points; East Europe's score was the lowest, but still as high as 62.3 points. Scores of Asian
regions were the lowest in the six continents, with South Asia having the highest score and Southeast Asia having the lowest among all regions. Africa’s score was on the moderate level, and scores of regions were about 68 points; East Africa and Central Africa scored the highest 68.8 points and South Africa had the lowest score, still arriving at 66.9 points.

With respect to EMC, scores of six continents showed no big difference, with Oceania having the highest score and Europe next to it; scores of Asia and Africa were lower than 50 points, especially within Africa where only Central Africa scored over 50 points and the lowest score was as low as 36.4 points. In Asia, all regions obtained low scores, except for East Asia, the other 4 regions all scored below 50 points; European regions' scores were all above 50 points, and Central Europe had the highest EMC score 55.9 points, which was also the second highest score among all regions of the six continents.

With respect to EHC, scores of six continents were all relatively high with big difference, in which South America had highest score 72.8 points and next to it was North America and Europe, but scores of Africa and Oceania were lower. Asian scores showed big difference; with Southeast Asia having the highest score 70.7 but Central Asia having the lowest scores 56.8, also as the lowest among all regions of the six continents.

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<td>Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Africa</td>
<td>47.0</td>
<td>16.4</td>
<td>40.1</td>
<td>68.8</td>
<td>45.5</td>
<td>64.2</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>47.3</td>
<td>14.9</td>
<td>48.2</td>
<td>66.9</td>
<td>49.1</td>
<td>57.3</td>
<td></td>
</tr>
<tr>
<td>West Africa</td>
<td>45.0</td>
<td>14.8</td>
<td>42.0</td>
<td>67.7</td>
<td>42.9</td>
<td>57.6</td>
<td></td>
</tr>
<tr>
<td>North Africa</td>
<td>45.2</td>
<td>11.5</td>
<td>43.5</td>
<td>67.7</td>
<td>36.4</td>
<td>67.1</td>
<td></td>
</tr>
</tbody>
</table>
5.5 Main Features of GEC

The GEC evaluation indicator system is a comprehensive evaluation system composed of 1 primary indicator, 5 sub-indexes, 16 pillars and 60 individual indicators covering five aspects, i.e. REC, EEC, ECC, EMC and EHC. Within this system, every part is closely related, infiltrating and influencing one another and their inherent uniqueness and relevance. Accordingly, the evaluation results of GEC comprehensively represent the development level and competitive strength of the countries in the five aspects of resource environment, ecological environment, environment carrying and environment management. Of course, the environment competitiveness of all countries also show some characteristics and rules, both the general rules universally existing in each country and the special rules determined by the different national conditions.

Through the evaluation on GEC of 2012, this report objectively and comprehensively analyses the development level and the gap of GEC, profoundly understands and grasps the development laws and characteristics of all countries, and recognizes the essence and inherent features of GEC. It's of great theoretical and realistic significance to research and find the right approaches, methods and counter measures so as to direct the countries to enhance the environment competitiveness by taking corresponding measures based on the special national conditions of them.

5.5.1 Environment competitiveness is the overall representation and combined result of economic, social and natural environment, reflecting the capacity and level of the countries on sustainable development.

GEC covers the five aspects of resource environment, ecological environment, environment carrying, environment management and environment coordination. Besides the influence of natural resource environment, it also reflects the comprehensive influence of economic and social factors on natural environment. So to speak, environment competitiveness is the overall representation and combined result of economic, social and natural environment; it reflects the capacity and level of the countries on sustainable development in an all-around way. Such a feature is represented in the setting of the indicator system and the variation of the evaluation results of environment competitiveness as well.

According to the evaluation and comparative analysis on environment competitiveness of all the countries, it is observed that: the developed countries behave well on environment competitiveness generally while a majority of developing countries behave poorly, showing a large difference between the developed countries and the developing countries. According to the behavior of sub-indexes, a majority of the countries
with higher scores of sub-indexes (except for EEC) are developing countries; the developed countries remain only intermediate level. Comparing with developed countries, many developing countries are "crippled". A majority of them are not balanced on the sub-indexes and thus the developed countries are still higher than the developing countries on overall environment competitiveness. For example, Morocco, ranking 95 th on environment competitiveness: both the ECC and EHC rank ahead, at 13 th and 33 rd respectively; but the REC, EEC and EMC rank behind, at 119 th , 102 nd and 97 th respectively, which drags down the overall ranking of environment competitiveness greatly. As a further example, Bangladesh, ranking 99 th on environment competitiveness: the REC, ECC and EHC all rank ahead, 4 th, 74 th and 41 st respectively; but the EEC and EMC rank behind, 132 nd and 119 th respectively. Thus the overall environment competitiveness ranks behind. There are also other developing countries like this, such as Guinea, Oman etc. Either one or two sub-indexes of them rank far behind and drag the overall environment competitiveness. On the contrary, the developed countries are balanced on the sub-indexes. For instance, Norway, ranking 3 rd on environment competitiveness: none of any sub-indexes ranks ahead except REC, but all the other sub-indexes ranks not behind, about 20 th. No serious "Short Slab" indicator for Norway and so, Norway enjoys very high environment competitiveness overall. As a further example, Finland, ranking 28 th on environment competitiveness: it also has not any sub-index ranking pretty high or very low, EEC (32 nd) the highest and ECC (85 th) the lowest, and all the sub-indexes are balanced. So, Finland ranks relatively high on environment competitiveness (as shown in Table 8-1).

The analysis above indicates that GEC is the result of five aspects working in concert: REC, EEC, ECC, EMC and EHC. All of them shall develop in a balanced way; a short slab tends to cumber the enhancement of overall competitiveness and results in the backwardness of overall environment competitiveness. Only when all behave well, they can support the overall advantage of environment competitiveness. Furthermore, it also indicates the crucial importance of analysis on sub-indexes, pillars and even individual indicators. Merely by the primary indicators, we may not make a correct analysis on the inherent factors and variation characteristics of environment competitiveness: the essence is likely to be concealed behind the appearance. While by focusing on the analysis of sub-indexes, pillars and individual indicators, we could make profound analysis on the essential characteristics and the real reason of changes for environment competitiveness. During the development process hereafter, the countries should focus on all the aspects of environment competitiveness, advancing in a comprehensive and coordinated way. Much importance should be attached to and effective measures should be taken for those indicators ranking behind especially, thus to improve and enhance them and to ensure the advantage of environment competitiveness.

Table 5-4 Rankings of Representative Developing Countries and Developed Countries on Environment Competitiveness and Sub-indexes

<table>
<thead>
<tr>
<th>Rank</th>
<th>Environment</th>
<th>REC</th>
<th>EEC</th>
<th>ECC</th>
<th>EMC</th>
<th>EHC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.5.2 ECC contributes the most to the overall score of environment competitiveness, the countries differs slightly on the scores of REC and ECC and differs greatly on the scores of EEC, EHC and EMC.

Figure 5-7 depicts the contribution rates of GEC sub-indexes to the primary indicator (i.e. the environment competitiveness). According to this figure: ECC contributes the most to environment competitiveness at the rate of 27.0%; EHC also contributes a lot with the rate up to 26.2%; EEC and EMC both contributes at 19.8% and REC contributes the least, only at 7.2%. Therefore, during the process of enhancing the environment competitiveness, the countries shall focus specially on ECC and EHC, while not ignoring REC, EEC and EMC.

![Figure 5-7 Contribution Rates of Sub-index Scores of GEC](image-url)

According to the analysis before, it is also observed that EEC, EHC and EMC have the standard deviation of 9.3, 9.1 and 8.9 respectively, which are both the main factors causing the environment
competitiveness differences among the countries. Relatively, REC and ECC have lower standard deviation, 6.8 and 5.3 respectively, of which, ECC has the lowest standard deviation and exerts the least influence on the environment competitiveness differences among the countries. It also means the environment competitiveness differences among countries are mainly represented in EEC, EHC and EMC with little differences in ECC. Therefore, the countries with larger differences of environment competitiveness from the other countries shall specially step up their efforts in EEC, EHC and EMC to narrow the differences and catch up.

Furthermore, it can also explain why the REC scores of developed countries are lower than those of most developing countries but the overall environment competitiveness scores are still higher: because many developed countries though are lower than the developing countries at the REC scores with wide margin in ranking, the contribution rates of REC to environment competitiveness are not very great due to the little and not obvious differences of REC scores among the countries; so the overall environment competitiveness of developed countries are influenced slightly by REC. Besides, the developed countries score higher on the other four sub-indexes, surpassing most developing countries, so the environment competitiveness of developed countries is higher than that of most developing countries finally.

5.5.3 Developing countries and developed countries differ greatly, and the emerging market countries have much room for improvement.

Table 5-5 compares the average scores and contribution rates of developed countries, developing countries and emerging market countries on environment competitiveness and the sub-indexes. It should be noted that United Nations Educational Scientific and Cultural Organization (UNDP) modified the groups of countries in Human Development Report 2010 issued on Nov. 4, 2010 and makes the number of developed countries or regions up to 44. In this way, of the 133 countries covered in this report, 34 are developed countries and 99 are developing countries. What's more, the non-developed countries of G20 are recognized as emerging market countries, 10 in all, including Brazil, Indonesia, Mexico, Russia, Saudi Arabia, Argentina, Turkey, China, India and South Africa.

It is observed from Table 5-1 that developing countries and developed countries differ greatly: the developed countries score 53.0 points on environment competitiveness, 4.5 points higher than that of the developing countries and 3.3 points higher than that of the emerging market countries; the developing countries score lower than the developed countries on all sub-indexes, and there are very large differences on EEC and EMC, respectively 12.2 points and 7.1 points. Emerging market countries score slightly higher than that of developing countries on overall environment competitiveness, with the difference of 1.2 points. But it has a big gap with the developed countries, with the difference of 3.3 points. The score of emerging market countries on EEC are very low, even lower than that of developing countries, and 12.9 points lower than that of developed countries. It greatly pulls down the overall score of environmental competitiveness of emerging market countries.
According to the contribution rates of sub-indexes to environment competitiveness, in developed countries, the contribution rate of REC to environment competitiveness is the lowest, just 6.74%, and the contribution rates of other sub-indexes are higher than 20%. Therefore, even though the contribution rate of REC is close to that of the developing countries and is lower than that of emerging market countries, it has no great influence on environment competitiveness and the inferiority of REC can be easily mended by the superiority of other four sub-indexes thus the overall environment competitiveness score is still higher than that of the developing countries and emerging market countries.

Furthermore, according to the country distribution of each echelon for environment competitiveness, among the 34 developed countries, 8 are placed in the first echelon, accounting for 80%; while among the 99 developing countries, only 2 are placed in the first echelon, showing great difference. The number of developed countries in the second echelon is 2 lower than the number of developing countries. Quite a number of developing countries are placed in the third-fifth echelons, 86 in all, accounting for 86.87 of the total; while among the 34 developed countries, only 17 are placed in the third-fifth echelons, only accounting for 50.0% of the total. In the fifth echelon, only 2 are developed countries, while up to 31 are developing countries, accounting for 93.94% of the total in the fifth echelon. The emerging market countries behave not so well in environment competitiveness as in economy. Only 1 of them is placed in the first echelon and the rest are all in the third-fifth echelons, among which, 6 countries are placed in the fourth echelon, accounting for 60% of the total.

All the above indicate the developed countries behave well in environment competitiveness, score high and rank ahead; while most developing countries score low and rank behind in environment competitiveness and the emerging market countries should also enhance their environment competitiveness further.

Table 5-5 Average Scores and Contribution Rates of Different Types of Countries in Environment Competitiveness and Sub-indexes

<table>
<thead>
<tr>
<th>Country</th>
<th>Environment Competitiveness Scores</th>
<th>REC</th>
<th>EEC</th>
<th>ECC</th>
<th>EMC</th>
<th>EHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed Countries</td>
<td>53.</td>
<td>100.00</td>
<td>17.</td>
<td>6.74%</td>
<td>58.</td>
<td>21.95%</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>48.</td>
<td>100.00</td>
<td>17.</td>
<td>7.35%</td>
<td>46.</td>
<td>18.97%</td>
</tr>
<tr>
<td>Emerging Countries</td>
<td>49.</td>
<td>100.00</td>
<td>18.</td>
<td>7.23%</td>
<td>45.</td>
<td>18.19%</td>
</tr>
</tbody>
</table>
Table 5-6 Number and Ratio of the Countries in Each Echelon of Environment Competitiveness

<table>
<thead>
<tr>
<th>Country</th>
<th>First Echelon</th>
<th>Second Echelon</th>
<th>Third Echelon</th>
<th>Fourth Echelon</th>
<th>Fifth Echelon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Ratio</td>
<td>Number</td>
<td>Ratio</td>
<td>Number</td>
</tr>
<tr>
<td>Developed Countries</td>
<td>8</td>
<td>%</td>
<td>9</td>
<td>%</td>
<td>8</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>2</td>
<td>%</td>
<td>11</td>
<td>%</td>
<td>22</td>
</tr>
<tr>
<td>Emerging Market Countries</td>
<td>1</td>
<td>%</td>
<td>0</td>
<td>%</td>
<td>2</td>
</tr>
</tbody>
</table>

5.5.4 Scores of environment competitiveness differ slightly among the regions but the ranks differ greatly: the countries of Oceania, Europe, South America and North America rank ahead while Asian and African countries rank behind.

Table 5-7 lists the average scores of the 133 countries covered in this report by continent (six continents, omitting Antarctica due to no country there) on GEC as well as the numbers and ratios of the countries in the first and second echelons in 2012. As shown in Table 8-4, in 2012, Oceania scores the highest in environment competitiveness, up to 56.3 points; South America, North America and Europe also score rather high, hitting 53.5, 53.0 and 52.3 respectively; Asia and Africa score the lowest, 47.5 and 46.7 points respectively. The score ratio of the six continents is 1.02: 1.12: 1: 1.20: 1.13: 1.14, with little differences.

The score differences are little among the continents but the ranking differences are rather great. In number, Europe enjoys the most countries in the first echelon, 6 in all; other continents have 1 country in the first echelon respectively except Africa.

Europe still enjoys the most countries in the first and the second echelons, 12 in all, far beyond the other continents; North America and South America the next, 7 and 6 respectively in all; both Asia and Oceania have 2 countries; Africa have only 1. In ratio, Oceania enjoys the highest ratio of the countries in the first echelon to total countries of it, up to 50%, and then Europe, South America, North America and Asia; Africa is 0. By further analysis, Oceania hits 100% for the ratio of the countries in the first and second echelons to total countries of them, and then South America, North America and Europe. Asia and Africa
both have low ratio, 5.13% and 3.03% respectively.

Therefore, both in number and in ratio, Oceania, South America, North America and Europe are strong on GEC with wide gaps from the other continents in ranking and holding the front places in the rankings. In view of the specialty of Oceania (only two countries of New Zealand and Australia), it's normal to score high and rank ahead. South America and North America are also very strong on environment competitiveness, above a half of the countries for the both placed in the first and second echelons. Among the 36 countries of Europe covered in the evaluation, 30% of them are placed in the first and second echelons, indicating its strong environment competitiveness. Asia and Africa are weak in environment competitiveness, as respectively 39 and 33 countries are covered in the evaluation, but Asia has only 1 country falling into the first echelon and even Africa has none; in the second echelon, there are both only 1 country, at the ratio of 5.13% and 3.03% respectively. Therefore, Asian and African countries shall enhance their environment competitiveness further.

Table 5-7 Average Scores of the Six Continents in Environment Competitiveness and Numbers and Ratios of the Countries Placed in the First and Second Echelons

<table>
<thead>
<tr>
<th>Item</th>
<th>Environment Competitiveness</th>
<th>Number and Ratio of the Countries in the First Echelon</th>
<th>Number and Ratio of the Countries in the Second Echelon</th>
<th>Number and Ratio of the Countries in the Third Echelon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Average Score</td>
<td>Number</td>
<td>Ratio</td>
<td>Number</td>
</tr>
<tr>
<td>Asia (39 countries)</td>
<td>47.5</td>
<td>1</td>
<td>2.56%</td>
<td>1</td>
</tr>
<tr>
<td>Europe (36 countries)</td>
<td>52.3</td>
<td>6</td>
<td>16.67%</td>
<td>6</td>
</tr>
<tr>
<td>Africa (33 countries)</td>
<td>46.7</td>
<td>0</td>
<td>0.00%</td>
<td>1</td>
</tr>
<tr>
<td>Oceania (2 countries)</td>
<td>56.3</td>
<td>1</td>
<td>50.00%</td>
<td>1</td>
</tr>
<tr>
<td>North America (13 countries)</td>
<td>53.0</td>
<td>1</td>
<td>7.69%</td>
<td>6</td>
</tr>
<tr>
<td>South America (10 countries)</td>
<td>53.5</td>
<td>1</td>
<td>10.00%</td>
<td>5</td>
</tr>
</tbody>
</table>
References


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[37] Zeng Fanyin, Feng Zongxian: "China's international competitiveness" Based on the environment, "Economist" 2001 No. 5