China Council for International Cooperation on
Environment and Development

The New Era of Green Development

——China's Green Transition to 2050

Discussion Paper

Task Force
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Disclaimer: This discussion paper is for soliciting comments, and does not necessarily represent the views of CCICED or the institutions the authors are affiliated to.

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To the reader

This is a discussion paper on China's green transition to 2050. It has been distilled from the ongoing work of the CCICED Task Force on this subject. It aims to solicit opinions from the participants to the 2017 annual general meeting of the CCICED.

This discussion document describes the vision and envisaged analysis of the task force on China's green transition. It covers a wide range of topics, each of them complex in itself, for example, the transformation of China's energy system, or the redefinition of China's urban-rural interface in the light of many changes going on and expected. The task force is of the opinion that the scope of analysis of China's transition has to be comprehensive in order to be relevant. Thus, hard as well as soft issues come to the table, and well-defined and as well as tentative issue frames.

Given the scope and main components as outlined, you are asked for your different opinion on the following:

- which of the issues merits focusing on, more than all others, in terms of evidence or other underpinning, and in what sense?
- what potential overarching policy recommendation appeals to you above all others and what motto would you give it?
- what are key dimensions for follow-up work, digging deeper either in order to provide advanced advice to China's leadership, and/or to learn from China's transition from an international perspective?

As an alternative to reviewing the whole paper, we draw your attention to the summary.

Ideally, we welcome your interventions during the 2017 AGM of the CCICED. Otherwise, please write within two weeks of the AGM (i.e., before 25 December 2017) to the executive vice-chairs of the task force: Yongsheng Zhang zys@drc.gov.cn and Jan Bakkes jan.bakkes@pbl.nl

Table of Contents

Table of Figures

Summary

The 19th National Congress of the Communist Party of China proclaimed that after long-term efforts, socialism with Chinese characteristics has entered a new era. After realizing a moderately prosprous society in all respects by 2020, China will basically realize its modernization by 2035 and become a great modern socialist country by 2050. To achieve this goal, why are the ecological civilization and green transition so crucial? Under the concept of green development, how will China reshape its modern economic system, spatial pattern and infrastructure, and what will they look like in 2050? How to design a policy framework and a roadmap for China to achieve its goal of green transformation? The report aims to provide initial answers to these questions.

Key Messages of the Report

The trigger of green transformation lies in the environmental crisis. However, to solve environmental problems, we must fundamentally reflect on the development model established after the industrial revolution and transform the mutually conflicting relations between economic development and the environment into a mutually compatible and even mutually reinforcing relationship. Green transformation is the most comprehensive and profound change in the mode of development after the industrial revolution. Its depth and breadth far exceed the commonly recognized environmental problems.

This report seeks to innovate from two aspects: first, it thinks outside the perspectives of the environment and energy sectors and seeks to address environmental issues from a broader perspective of the transformation of development modes. Second, the analysis and policy recommendations of this report are intended to build on the profound reflection on the traditional development model that causes serious environmental problems. It envisages environmental protection becoming a driving force for economic development.

One key message of this report is that the traditional mode established after the industrial revolution, though has brought great progress to human society, is unsustainable, while existing theories, models, institutions and policy systems on development are produced by and catering for the traditional industrial age and to

some extent are conflicting with ecological civilization. The traditional industrialization mode must obey the logic of ecological civilization and carry out systematic transformation on the basis of ecological civilization.

Unlike the general perception that green transformation is a burden, the paper argues that the existing conventional pattern of development based on the industrial age is indeed a high-cost economy in the form of hidden, external, long term and opportunity costs which are often neglected. A green economy based on ecological civilization is a new type of economy that costs less, is more efficient, and represents the future direction, although this transition will be arduous.

Green development means great opportunities. The report of the 19th National Congress of the Communist Party of China pointed out that the major contradictions in China have changed into one between people's ever-growing needs for a better life and unbalanced and insufficient development. People's growing needs for a better life, to a large extent, must be satisfied by new green supply. It means that a great deal of opportunities will emerge as a new source of economic growth, which is exactly the core of green development.

The second key message is that China's green transition over the next decades should be understood as a comprehensive process, involving simultaneous changes in its economic structure, demography, urban-rural relations and social development as well as China's role in the world.

The third key message is that the happening of China's green transition should not be taken for granted. In order to unleash the potential for China's transition, innovative and firm policies are essential, as well as adaptive planning.

The fourth key message, derived from modeling work of the Task Force is that，like all other countries, China's green transition by itself, would be insufficient to place China on a path that is consistent with achieving the internationally agreed target of limiting global average temperature increase to 2℃ above pre-industrial levels. Additional, globally concerted and targeted policies are needed and doable.

The Potential of China's Green Transformation in 2050

China's green transformation will take place in two directions: First, the greening of the mode of production means that the production will be conducted in a greener way. For instance, by investing in mature green technologies that are cost-effective can generate significant investment needs. Second, the greening of lifestyles means production and consumption of greener content. All these mean that green supply and

demand will emerge based on sound ecological environmental assets, or turning "Green" into "Gold".

According to these two transformation directions, if the 2035 targets are based on "what can be done" and the 2050 targets are “what must be done" for achieving global sustainable development, the green transformation to 2050 in China will have the potential to achieve the following developments:

The economic growth rate of the green transition scenario will be roughly the same as the conventional scenario (BAU) at the early stage of the transition, but the green transition scenario will outpace the BAU scenario by around 2035.

The green transition has a substantial economic impact. Above all, this is reflected in the growth of the service sector --- existing as well as emerging services. In 2035, the difference in GDP composition between business as usual and the green transition scenario can be attributed for 74% to the service sector. By 2050, this would have risen to 82%. In addition to emerging service sector, more services will be embodied in industrial and agricultural production.

The ecological environment has been greatly improved. Under the green transition scenario, environment has been fundamentally improved in 2035 and by 2050 environmental indicators further improved to achieve excellent or good quality standards of advanced nations, thus satisfying the target of building a beautiful China.

In addition, the paper tables results of a first analysis of how to shape the modern green economy (green transformation of the industry, agriculture and services), the spatial pattern (new urban, rural areas and urban-rural relations) and the green infrastructure. It will occasionally touch upon root causes of environmental degradation and, more importantly, suggest the direction of the transformation, potential scenarios as well its challenges.

Policy Framework Recommendations

However, to make this vision of "more protection, more development" a reality is no easy task. We must overcome various obstacles and establish a specific mechanism and a roadmap for transforming, as the Chinese motto says, "green" into "gold". For this reason, in the process of policy making, various obstacles or challenges should be addressed, which can be categorized into six types, including cognitive issues, fair competition, institutions, the role of the government, social equity and global coordination.

Overall Strategic Objective: To speed up green transformation in an all-round way based on the concept of ecological civilization and new development. Through the comprehensive transformation of development concepts, contents, modes, mechanisms and policy systems, China shall speed up the establishment of a new development paradigm of mutually-reinforcing "Five in one" relation between economy, environment, culture, society and politics.

Roadmap: 2035 is a pivotal year for green transition. The focus of 2020-2035 is to catch up and transform key systems. And the focus of 2035-2050 is to take on a leading role in some aspects and strive for a better vision, the success of which depends on the realization of the targets by 2035. The catching-up until 2035 is more than just the fundamental improvement of the environment, but also to establish a new green development model on the basis of ecological civilization and go beyond the traditional industrialization model.

The green transition is holistic, profound, which needs to achieve systematic breakthroughs through comprehensively deepening the reform. This paper structures its recommendations on institutional arrangements and policies according to the following six pillars.

Pillar one is to achieve a breakthrough in establishing a new green development narrative. The stringent environmental policies and green development can be fully implemented only after achieving breakthrough in understanding the relationship between environmental protection and economic development. Let all levels of government and people truly understand the difference between green development based on ecological civilization and the traditional development model. It is necessary to make the abstract concepts of ecological civilization and green development actionable through innovative thinking, green education, pilots and etc.

Pillar two is to achieve a breakthrough in key environmental issues and to level the playing field for the green industry. Regarding the current prominent environmental problems like air pollution, food contamination, soil pollution, water pollution and ecological restoration, more stringent standards should be developed and implemented. The strict pollution control is the greatest support to the green economy.

Pillar three is to achieve a breakthrough in green development mechanisms and to conduct pilot projects in some areas. We should carry out systematic reform on institutions and policies that are inconsistent with green development, including promotion of new development performance measurement based on the standards of a better life, natural capital assessment, performance assessment of local officials, land management, taxation and finance.

Pillar four is to achieve a breakthrough in the new green promotion action. By introducing landmark policies, China can boost the confidence of green development, promote green economy and forge a future-oriented digital green economy.

Pillar five is to achieve a breakthrough in building a more inclusive society and resilient economy. Through national policies like transfer payment, industries, regions and groups that have been affected directly during the transformation would also benefit from this process. The policy should also help cope with changes in business models, local identity and various career changes.

Pillar six is to achieve a breakthrough in promoting the establishment of a global governance mechanism for green transformation and promote coordinated action for the international community.

In short, China's green transformation, if successful, will not only benefit itself but also the whole world. If China can successfully explore a new path towards green development in the digital era, it will be a major contribution to the community of common destiny and the modernization of low-income countries in a leapfrog fashion so as to avoid the traditional development path of "pollute first and treat later ".

Most part of this document has been done by the team at Development Research Centre of the State Council of China. In addition, the following main inputs have been provided by the international experts.

A model-based scenario-analysis of the worldwide context of China's green transition to 2050. This study is meant as a kick-start for fuller analysis. It will be available in print and as pdf for participants to the AGM. It can also be downloaded from www.pbl.nl

A quantified scenario depicting China stopping straight away with investments in fossil fuels. This has been contributed by Jorgen Randers and is available upon request.

Introduction

This paper is an output of "China's Green Transition to 2050" task force of the China Council for International Cooperation on Environment and Development (CCICED) for 2016-2017. It addresses three major questions:

First, why China needs to make green transition, what are the fundamental causes, opportunities and global significance.

Second, where is the transition going to, that is, what are the fundamental changes to China's economy from green transition, including the basic directions, prospects and challenges of reshaping the modern green economy, spatial pattern and infrastructure.

Third, how to achieve the goal of transition, that is, the policy framework design and roadmap for transition.

Given the scale and width of the topic, the purpose of the study is to produce a framework that starts from current initiatives and rapidly scales up, moves forward efficiently, and adjusts by taking advantage of innovation.

From a global and historical perspective, China is at a historic juncture in the intersection of three major changes, and the world in 2020-2050 will be vastly different.

First, the 19th National Congress of the CPC proclaimed that after long-term efforts, socialism with Chinese characteristics has entered a new era. After realizing an all-round well-off society in 2020, China will set a goal of realizing basic modernization in 2035 and becoming a great nation in 2050.

Second, after more than two hundred years of entering the industrial age from the agricultural age, human society is entering the digital age. This epochal change is revolutionizing the 'rules of the game' and has the potential of completely changing the economic development in the traditional industrial era, including the concept of resources, the mode of business organization and the content of development.

Third, after experiencing various environmental crisis caused by "excessive resource consumption, great environmental loss and high carbon emissions" in the industrial era, the people's development philosophy is undergoing

fundamental changes. The concepts and models of development based on the traditional industrial civilization are being replaced by those based on ecological civilization. Green development has increasingly become the mainstream concept of development in the world.

Before the Industrial Revolution, China had been one of the largest economies and the richest countries in the world. After the Industrial Revolution, the countries represented by Western Europe took the lead in realizing the so-called modern economic growth based on industrialization and obtained rich material wealth and prosperity. China, with its agriculture as its mainstay, became a so-called backward country for a long time. Only by the middle of the twentieth century did China fully embark on the process of industrialization and won the miracle of development. The industrialized growth pattern and lifestyle are not only regarded by underdeveloped countries, including China, as a model for economic modernization, but also as the inevitable laws and paths for economic development.

However, the traditional development model characterized by "high resource consumption, huge environmental loss and high carbon emissions" has also brought about a global crisis of resources and environment. China paid a heavy toll on the environment. This global environmental crisis is not just a matter of environment and energy, but a crisis of development paradigm. The whole set of existing theories, models, systems and policy systems on development are the products of the industrial age. They are largely in conflict with the ecological environment. All countries, including China, need comprehensive and profound green transformation.

In recognition of the unsustainability of the traditional development model, China has coined the new concept of ecological civilization, and has begun the historical course of green transformation. The trigger of green transformation is environmental crisis. However, to solve environmental problems, we must fundamentally reflect on the development model established after the industrial revolution and establish a new development paradigm. The conflict between economic development and the environment should be transformed into a mutually compatible and reinforcing relationship.

Green transformation is the most comprehensive and profound way of development after the industrial revolution. Its depth and breadth far exceed the commonly recognized environmental problems. To this end, this report seeks to innovate from two aspects: first, it thinks outside the perspectives of the environment and energy sectors, and seeks to resolve environmental

problems from a broader perspective. The content and ways of development determine its environmental consequences, so environmental issues are not only related to the environmental protection departments, but all departments concerned. Second, the analysis and policy recommendations of this report are intended to build on the profound reflection on the traditional development model that causes serious environmental problems. The objective is to not only solve environmental problems fundamentally, but also make environmental protection a driving force for economic development.

The traditional industrialization model has brought tremendous progress to human society, but it is largely unsustainable. When it expands infinitely according to its own logic, it will inevitably overstep the boundary between man and nature, thus bringing about unsustainable human development. Therefore, the industrialization must obey the logic of ecological civilization. The set of ideas, models, systems and policies on development established in the traditional industrial era must be systematically transformed on the basis of ecological civilization, and a new paradigm of sustainable development must be established.

The green transformation represents a major opportunity. It can not only improve the quality of growth, but is likely to become a new source and driving force of growth. Unlike the perception that green transformation is a burden, it argues that the existing conventional development model causes real high-cost. However, these costs are mostly ignored in the form of hidden costs, external costs and opportunity costs. A green economy based on ecological civilization is a new type of economy that is truly cheaper and represents the future direction, though this transformation will be arduous.

However, to understand and identify the opportunities for green development, we must "think outside the box" and have new ideas, way of thinking and vision. The mechanism of green development is largely a self-fulfilling process. As more and more people believe that green development will come true and take action, the green market will expand and resources will increasingly converge in this direction, and more and more green success stories will emerge. A virtuous circle of "action-evidence" would then appear.

It should be emphasized that the scenario analysis of China's Green Transition to 2050 in this paper is more like conceptual analysis than forecasting. Given the immense complexity of China’s development at this point in time, there is currently no analytical tool that allows for a precise quantitative forecast of development in the decades to come. Therefore, the

focus of this report is not a precise quantitative outlook for 2020-2050, but an exploration of the problems behind the transition. We will suggest institutional and policy recommendations on how green transformation can enhance the quality of growth and accelerate development. Given such a framework, the specific shape and size of the future green economy in China can be a natural evolutionary process.

If China could successfully explore an effective green development model, it will not only benefit itself, but also serve as a reference for other developing countries and make a significant contribution to sustainable development in the world.

Chapter One Green Transformation: Entering A New Era

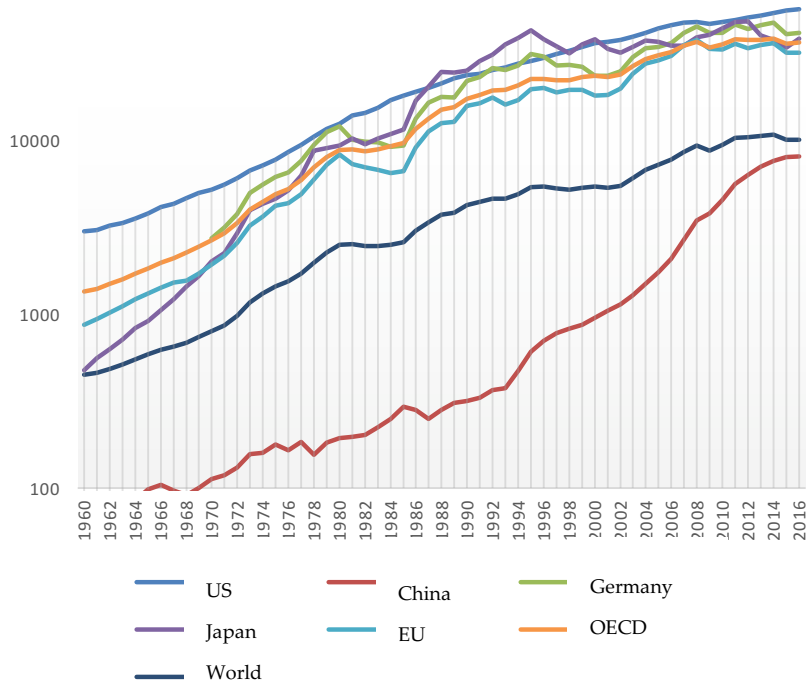
Section 1 From Industrial Civilization to Ecological Civilization

1.1Great Industrial Civilization

Since the industrial revolution in the eighteenth century, the industrialization model established by industrialized countries has brought about tremendous progress in material productivity and liberated mankind from the material shortages in agrarian society. The reconstruction of social relations based on the principle of market has greatly enhanced people's freedom and promoted the development of human civilization. Economies represented by industrialized countries took the lead in realizing an affluent society through industrialization and this model has been adopted in many other countries. There is no doubt that industrial civilization represents a great advance in human history.

Since the middle of the last century, China began its miraculous process of industrialization. In particular, after the reform and opening up in 1978, the economy has maintained a rapid growth of about 10% per annum. Over the past four decades, China's GDP has increased more than 30 times and per capita GDP has increased by more than 20 times. In a very short period of time, it moved from being one of the poorest countries to the second largest economy in the world, an unprecedented achievement in human history (NBS, 2017; Figure 1).

Fig 1 The change of GDP per capita in countries 1960-2016 (current price)



Source: World Bank public database
https://data.worldbank.org

1.1 High Price of Traditional Industrialization and Root Cause behind

1.2.1 High Price of Traditional Industrialization

However, the story has another side. After the Industrial Revolution, the traditional industrialization model of "pollution first, cleaning-up later" has brought serious environmental consequences. China, following this industrialization model, has also encountered the same environmental problems. While the material wealth rapidly expands, China has paid huge environmental and social costs. In other words, it is the principle contradiction between “people's ever-growing needs for a better life and the unbalanced and inadequate development”, as put forward by the 19th CPC National Congress (Xi Jinping, 2017). From the perspective of green development, the "unbalanced and inadequate development" is mainly reflected in the following aspects.

- High costs: serious environmental consequences due to unsustainability

Due to the immense power acquired through industrialization, the relation between humankind and nature has been gradually transformed from passive adaptation to domination. The world has entered the so-called Anthropocene era in which mankind predominates the geology and ecology, and has a significant impact on the earth system. Rockstrøm (2009) and others have argued that the pressure of intensified economic activities may lead to the breakdown of one or more of the nine Planetary Boundaries. These are environmental thresholds or tipping points where irreversible and abrupt environmental change could undermine economic and social development. At worst, the continuation of human civilization could be threatened (e.g. Ripple, et al., 2012) [1].

The severe environmental problems caused by the traditional development model in China are noticeable, which include air pollution, water environmental problems, soil problems, habitat destruction, loss of biodiversity, etc. (Diamond, 2011).

- According to the Chinese government environmental bulletin, almost 60% of the underground water monitored was of poor or extremely poor quality in 2014; about 20% of the arable land was polluted. As for air pollution, four of the twenty most polluted cities in the world are in China (WHO, 2016).

- China's marine environment (including the Yellow Sea and South China Sea) is considered to be one of the most degraded waters in the world. Desertification is a serious problem, with the area of desertification still growing at a rate of 67 square kilometers per year. Habitat destruction and loss of biodiversity are also eminent.

- On climate change, although its historically accumulated greenhouse gas emissions per capita and per capita emissions are relatively low, China now has the largest emissions in the world on an annual basis.

- China is the largest resource consuming country in the world.

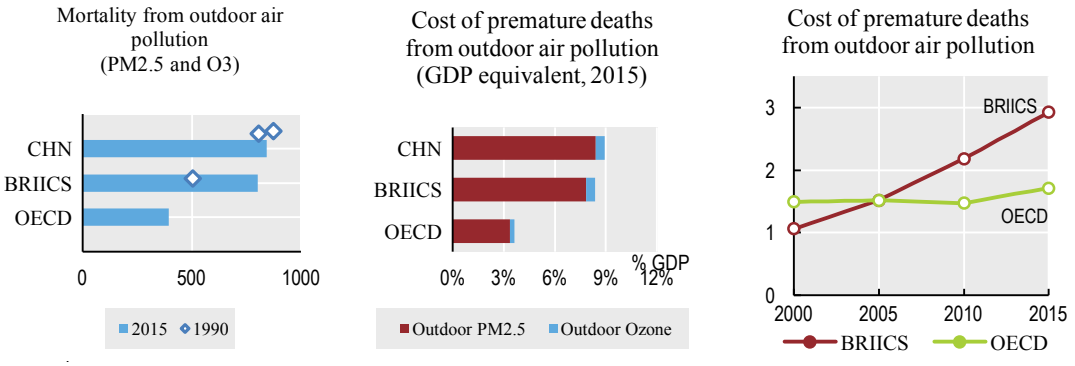
These not only affect the sustainability of development, but also seriously jeopardize the health and well-being of our generation. For example, airborne

[1] http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

particulates can penetrate into lungs causing cancer and respiratory diseases; contamination of surface water and underground water affects drinking water safety and food safety; heavy metals and toxic substances in the soil are enriched in crops and livestock products, causing food problems, and so on.

In the case of air pollution, air pollution causes premature death and increased medical costs. According to the OECD (2017), the social costs of outdoor PM 2.5 pollution in China in 2015 was 8.38% of GDP, while the number was 3.37% in OECD countries. The cost of indoor PM2.5 was 4.46%. The social cost of air pollution in 2015 was 4.46% of GDP (Figure 2). Although the exact figures for such estimates may be controversial, there is no doubt about the serious consequences of air pollution.

Fig 2 Air pollution weighs heavily on population's health and welfare



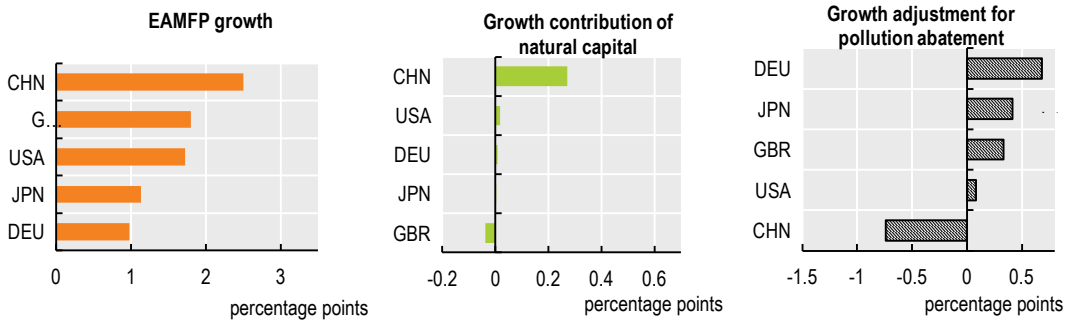
Source (mortality): recited from OECD (2017), which is based on GBD (2015), Global Burden of Disease Study 2015 Results. Mortality data on indoor air pollution from GBD are available for only some countries. They draw on WHO information and national household surveys.
Source (costs): produced based on Figure 10.5 in OECD (2017), which is based on OECD calculations using methodology adapted from OECD (2014).

The health hazards and loss of natural capital caused by environmental damage can be estimated through cost-benefit analysis (CBA). For example, the estimate of the U.S. EPA (unofficial) shows that it is uneconomical to use domestic coal in the United States. The benefit by utilizing coal to generate electricity is US$ 200 billion, but the health cost caused by PM2.5 and other pollutants due to the use of coal is US$ 300B ~ 800B (Machol and Rizk, 2013). Since coal accounts for more than 60% of its energy consumption, the health costs in China are even higher.

OECD estimates show (Figure 3) that China's growth still heavily depends on resource inputs. If the impact of environmental pollution was taken into

account, the average annual GDP growth rate from 1991 to 2013 would drop by 0.74 percentage points.

Fig 3 Productivity and the role of environmental services for growth of total economy, long-term average growth rate (circa 1991-2013)



Note: The coverage of environmental services remains partial, currently limited to air emissions and subsoil assets. The growth contribution of natural capital expressed as a long-term average growth rate in percentage points, and as a share of output growth. It measures how much current income growth depends on domestic natural resource use. The growth adjustment for pollution abatement expressed as a long-term average growth rate in percentage points, and as a share of output growth. It measures to what extent economic growth has been achieved at the expense of environmental quality. See also Glossary.
Source: based on Figure 5.2, in OECD (2017)

- High Growth, Low Welfare

The traditional growth pattern affects people's well-being in two ways. First, ecological damage and environmental pollution will reduce people's quality of life and well-being. Environmental issues such as air pollution, food safety, drinking water quality, noise, extreme weather and loss of biodiversity have infiltrated all aspects of people's lives and seriously affected their health and safety (e.g. Yang and Zhang, 2015). Second, economic growth centered on the production and consumption of material wealth is unlikely to improve people's quality of life and happiness at the same pace. Numerous studies show that in many countries, including China, economic development under the traditional industrialization model has not been able to continuously raise the national happiness level as people expected (e.g. Easterlin, et al., 2012; Ng, 2003; Scitovsky, 1992; Jackson, 2016; Skidelsky and Skidelsky, 2012). When the basic material needs are met, although the further expansion of material wealth can bring dazzling GDP figures, yet has little effect on continuous improvement of people's well-being.

In short, although the traditional industrialization model has brought high material productivity, it is a high-cost economy. However, this cost is not

reflected in the private sector, but takes the form of social, hidden, long-term, and opportunity costs, which are easily overlooked. At the same time, the effect of this growth model on people's welfare is also limited, while improving welfare is the fundamental goal of economic growth.

1.2.2 The root cause

The "unbalanced and inadequate" problems that have emerged in China's development are not an issue of bottleneck as usually thought, but an inevitable result of the traditional industrialization model. They can be only resolved by the systematic transition of development concept, modes, systems and policies. In fact, the Chinese government has attached great importance to these "unbalanced" and "inadequate" problems. For example, although environmental protection has been the basic national policy of China since 1983, environmental problems are still hard to solve because the contents and models of traditional growth are in nature based on sacrificing the environment.

The ecological and environmental consequences in China are, of course, caused largely by China's own extensive development model. But at the root they reflect the development paradigm established since the Industrial Revolution in the world. Industrial civilization with material production and consumption at its core has some inherent conflicts with environmental protection. The typical characteristics of industrialization are the mass production of a single industrial product through large-scale assembly lines and mass consumer society so as to bring the entire economy to continuous operation. It has become the primary goal of industrial society to stimulate people's desire for purchases and overconsumption through various means and to continuously expand consumption of products, so as to create profits and GDP growth (Goodwin et al., 2008; Mukerji, 1984). As for whether the consumption will improve people's well-being, it has become a secondary issue. The purpose and means of development are so unconsciously reversed. The original aspiration for development is therefore forgotten.

Under the power of industrialization, the entire society has been reconstructed according to the industrial logic. As a consequence of continuous expansion based on consumerism, not only the boundary between man and nature is broken, the complex social-economic-ecological system originally based on ecological logic is also dissolved by industrial logic, causing a large number of ecological crisis, and social and cultural problems.

Agricultural problems. Agriculture has been transformed by industrial logic from traditional ecological agriculture to the so-called "modern" agriculture characterized by monoculture, industrial agriculture and chemical agriculture, leading to serious agricultural non-point source pollution, declining soil fertility and ecological diversity loss.

Rural and regional problems. The rural population has massively migrated to urban and coastal areas with industrial advantages and the rural area has become a place providing agricultural products, raw materials and labor for industries and cities, and have formed the urban-rural gap and the regional gap in the basic structure of "urban-industry; rural-agriculture".

Devaluation of ecological and cultural resources. As industrial production relies mainly on material resources, a large amount of precious intangible resources (including ecological environment, humanities, intangible cultural heritage, etc.) in rural areas, or the so called "green resources", have little role to play in the material wealth-based industrial production. As a result, their value is not only difficult to be fully recognized, but even be ruined.

Social and cultural consequences. The consequence of the traditional growth model is further reflected in social and cultural aspects, including a large number of hollow villages, left-behind children, migrant workers, disappearance of villages and other social problems. When the production and lifestyle are completely changed by the industrial logic, then the rich local culture formed after thousands of years loses its foundation.

At the same time, over-emphasis on GDP has further mixed the purpose and means of growth. Simon Kuznets, one of the inventors of the GDP concept, warned that GDP cannot be used to measure the overall well-being of a country (Atkisson, 2012). Recently, some major efforts have been made internationally to develop indicators that measure better national well-being (Stiglitz, Sen and Fitoussi, 2009; OECD, 2007, 2011; European Commission, 2007) [2].

In short, the industrialization model has brought great progress to human society. However, under such model, it is difficult to form a harmonious

[2] For example, in 2007, the EU launched a 'Beyond GDP' initiative.2 The following year, French President Sarkozy established a Commission on 'Measuring Economic Performance and Social Progress' that addressed issues including the environmental quality of life and environmental sustainability.2 Building on the Commission's report, in 2011, the OECD launched its 'Better Life Initiative' that provides a framework and indicators to assess human-well being and social progress.

relationship between economic development and the environment, society, culture and governance. When economy expands indefinitely in accordance with the logic of industrialization, it will inevitably overshadow the boundary between man and the nature, resulting in unsustainable development.

1.2 The rise of ecological civilization

Since traditional industrialization model is unsustainable, green transformation emerges, which is not an issue of "whether or not", but how. Ecological civilization and the traditional industrial civilization have different logics in terms of development concepts, contents and organizational models. The core of the industrialization model is the production of material wealth, raising the productivity by means of single large-scale organization, while the ecological civilization in addition to the material wealth, also emphasizes the intangible value of ecological and cultural services. Its organizational models are "organically" grown in the complex socio-economic-ecological system. If industrial civilization is more of a violent conquer of nature by human beings, ecological civilization enhances people's well-being by smartly releasing the nature's power with respect, understanding, adaptation and utilization.

The logic of industrialization must obey the logic of ecological civilization. This will bring about two effects. On one hand, ecological civilization can refrain the powerful industrial forces from breaking the boundary between man and the nature. On the other hand, it expands the space for economic development since it goes beyond the material wealth limitation of traditional industrialization, and highly regards the non-material resources that are not adequately valued in traditional industrialization model, such as eco-environment and culture, as important sources of value creation. The whole set of ideas, models, systems and policies on development established in the industrial era must be systematically transformed and redefined on the basis of ecological civilization in order to establish the "Five in One" mutually reinforcing relationship among the economy, environment, society, culture and politics.

It is inevitable for China to put forward the concept of ecological civilization and new development. The green development model to be explored must absorb the essence of the traditional industrialization, and transcend it.

First, it is based on China's own experience and reflection on the development process. The industrialization achievements made by China in the short span of 40 years have never been seen in the history of the world and the lessons learned have been very profound. This makes China a unique test ground for the new development concept. This new concept will have profound and universal values for human development[3].

Second, the birth of ecological civilization in China has its profound philosophical and cultural foundations. China has always revered the nature with its ancient philosophy of "harmony between man and nature". This tradition is different from the logic of conquering nature by industrialization. The concept of a moderately well-off society in China is a mind full of wisdom. It does not regard mere material wealth as the prominent goal of pursuit, but reflects the philosophy of all-round human development.

The major conclusions of the 19th National Congress of the CPC about "remaining true to the original aspiration" and the shift of the principle contradiction in China, namely, "people's ever-growing needs for a better life and unbalanced and inadequate development" (Xi Jinping, 2017) have important implications to China's green transition to 2050.

First, green development requires systematic and profound transformation. The purpose of development or the "original aspiration" is to satisfy people's all-round needs so as to enhance people's well-being. Economic growth is only a means to improve well-being, not the purpose. When the material wealth is increased to a certain extent, the content of development should go beyond material wealth and turn to meet people's all-round needs, that is, "people's ever-growing needs for a better life" so as to enhance people's well-being.

Second, green development represents a huge opportunity. The shift in development content to meet people's ever-growing needs for a better life means a host of new opportunities that will accelerate economic growth. However, there will be big changes in the content of growth. These needs, which require new supplies to meet, can be a new and important source of economic growth. This is what green development is about.

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[3] If one understands the process of formulating important documents such as National Congress Report of CPC and the "Five-Year Plan" of the government in the past, he/she can then understand that these documents largely reflect the collective insight of the Chinese elites and their identification of contemporary China issues , in-depth analysis and forward looking.

Green development is the embodiment of ecological civilization in the mode of production and way of life. Based on ecological civilization, green development is to redefine development with new concept. Once out of the traditional industrialization thinking, a large amount of new resources, which were not regarded as resources in the past, will be found to produce new values and contents with the new organizational and business models, transforming "green" into "gold". The prospects of development will be bright.

The mechanism of green development is largely self-fulfilling. As more and more people believe that green development will come true and take action, the green market will expand and resources will increasingly converge in this direction, and more and more green success stories will emerge. A virtuous circle of "Action ↔ Evidence" will then appear. Under the new development concept and the logic of ecological civilization, the "five in one" mutually reinforcing relationship involving economic, environmental, cultural, social and political aspects is expected to be formed through the establishment of a new growth model, institutional mechanism and policy system.

One big problem facing the green transition is to establish a new narrative on green development in order to inform people of the great opportunities of green transition and the great harm of not doing so, and explore a feasible path towards it. To this end, the international community has made great efforts and done a lot of work on green development and green economy (e.g. OECD, 2017; Ho and Wang, 2014; Hsu, 2016; DRC and World Bank, 2012). At present, the mainstream argument is that the traditional mode of development is not sustainable because of huge environmental problems, and the solution to environmental problems requires higher costs, but the cost is within the acceptable range. However, in most narratives on green development, the costs of inaction and the great benefits of quick and persistent action on green transition are greatly underestimated. Therefore, there is an urgent need for new thinking, new theoretical methods and empirical evidence.

Section 2 Historic Opportunities of Green Transformation

As indicated in the introduction, from a global and historical perspective, during 2020-2050, China is at the intersection of several major historical changes. That is, the level of China's development has entered a new era. Human society is entering the digital age from the industrial age, while a large number of green technological breakthroughs are also taking place. At the same time, green development has not only become China's national strategy, but has also become a high public consensus. This means that China has the necessity, technological feasibility and capability for green transition. It is a time window for the transition from now until 2035 when modernization is basically achieved in China. With later-comer advantage, China can take the lead in realizing its green transition and becoming a frontier-runner in green development. If China misses this window of time, it may be locked in a traditional high-carbon path, and then transition costs will be very high afterwards.

2.1 China has entered a new era with strong capability for green transition

After nearly 40 years of rapid growth, China's economic development is at a new historical phase, shifting from a middle-income country to a high-income country. Its growth rate has also shifted from high to medium-speed. The 18th CPC National Congress proposed two centenary goals. At the 19th National Congress held in October 2017, China announced the goal of entering the new era of socialism with Chinese characteristics and the goal of building a moderately prosperous society in all-respects by 2020, and a two-steps strategy of realizing its modernization targets by 2020-2050 (Xi Jinping, 2017).

Step one: 2020-2035. On the basis of achieving a moderately prosperous society in all respects, to strive for 15 years and basically realize the socialist modernization.

Step two: 2035-2050. On the basis of the basically realization of modernization, strive for another 15 years to build China into a prosperous, democratic, civilized, harmonious, beautiful, strong and modern socialist nation.

After China enters a new era, economic growth is no longer the primary goal but it is still a necessary condition for modernization. The premise of China's green transition must be conducive to its realization of the established strategic goal. The policy recommendations for green transition under this premise, can then obtain sustained political momentum. Otherwise, they will be more difficult to be implemented.

The question to be answered now is whether green transformation can achieve similar growth rate as conventional growth while bringing higher environmental quality and efficiency. What is more, whether green transformation can become a driving force for growth. The answer is that as long as the reliance on the growth patterns of traditional material factors and material products shifts to the growth based on knowledge, ecology, culture and technology and produces new green consumption content, it is entirely possible that green transition will lead to higher quality and faster growth. This means that the core of green transition is to generate new green supply and new demands, and improve the efficiency of traditional sectors.

Fig 4 China's economic aggregates and forecasts 1978-2050

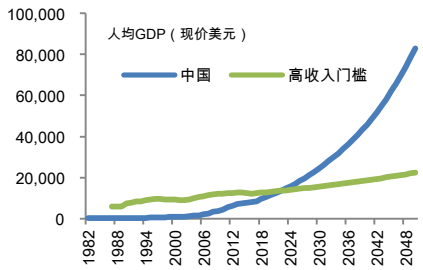
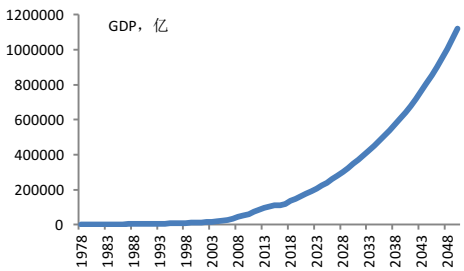


Fig 5 The time for China to cross the high income threshold in the BAU scenario 1982-2050



Source: DRC Growth Research Team

According to DRC Growth Research Team, China is expected to cross the threshold of high-income economy by 2023 under the BAU scenario and is expected to become the world's largest economy by around 2030. By 2050, GDP per capita is roughly 3.6 times the high-income threshold, close to the average of the then developed countries (Figures 4 and 5). The scenario of China's economic growth and the phase shift have brought both opportunities and challenges.

First, as the traditional growth momentum is close to exhaust, China needs to find new momentum and sources for growth, so as to ensure its

modernization goals. Green growth will become an important alternative source of new supply and momentum.

Second, as the income level rises, the preference and demand for green products in the Chinese market have risen sharply. As the second largest market in the world, China has provided huge market demand for various green supplies.

Third, over a decade or so of becoming a high-income country between now and 2035 is a time window for China's green transition. If China uses this time window to speed up the green transition, it can take advantage as the later-comer and can achieve a leapfrog development in many aspects. If China does not speed up its transition, once the Chinese economy is locked in a non-green state, the cost of transition will become higher.

2.2 The environmental "crisis shock" turns into momentum for green transition

The various environmental crisis and their consequences that have emerged under China's traditional industrialization mode are now being transformed into powerful engines for promoting green transition. This "crisis shock" has directly promoted the accelerated transition of China's development concept and unprecedented environmental protection efforts.

First, the environmental problem has become a constraint for development, forcing China to make a green transition. Without a green transition, the thresholds will be exceeded in the areas of air, soil, water, food, health, energy, and climate and beyond. The severe environmental policies promulgated by China include the Action Plan for Prevention and Control of Air Pollution (referred to as the "Atmosphere Protection Ten Articles"), the Action Plan for Prevention and Control of Water Pollution ("Water Protection Ten Articles"), the Action Plan for Prevention and Control of Soil Pollution (referred to as "Soil Protection Ten Articles"), as well as the environmental law enforcement. It is the result of forced reform. At present, China is setting off a storm of environmental law enforcement and environmental protection is becoming increasingly more stringent in the future (see CCICED's issues paper 2017)

Second, the enormous damage and unsustainability of the traditional model of development have enabled the people and decision-makers to build up consensus of green transformation, which turns into the driving force for

transformation. If in the past a lot of environmental issues were still quite distant from people's daily life, now the ecological environment has become the most concerned issues. Local governments that promote environmental protection often receive strong support from the public, while the inaction in environment often leads to public protests and social instability. The household survey conducted by the "China Livelihood Survey" team (DRC, 2015) shows that the respondents' subjective evaluation of the improvement of ecological environment quality is closely related to the overall satisfaction of their family life.

Third, people began to carry out a deep reflection on the traditional industrialization mode, and rethink the new mode of sustainable development. In the past four decades or so, China has achieved great success through industrialization, and has also thoroughly understood the problems of the model. This has led China to reflect on and put forward a new concept of ecological civilization on the basis of its own 5000-year of culture and traditional philosophy, putting green development as a national development strategy. The report of the 19th National Congress of the CPC pointed out: "The modernization we want is to develop harmonious coexistence between man and nature."

2.3 The arrival of digital age and coming breakthroughs of new green technology

One of the most important technological changes the world today faces is the advent of the digital era. Human society has brought tremendous changes from agricultural era to industrial era. From the industrial era to the digital era, it is also an epoch-making change. It is changing the "rule" of the economic development established in the traditional industrial era. Many concepts such as concept of resources, content of development, business models, economic organization and the pattern of urbanization are undergoing substantial changes which will have great implications to economic development, environment, and people’s well-being.

This change is a kind of "creative destruction" that has brought a host of new opportunities. It has made it possible for the developing countries to achieve leapfrog development with a new model. Of course, the digital economy does not necessarily imply a green economy. It merely creates more

technological conditions for the rise of green economy and business organization models. In particular, in China, the era of mobile Internet and the arrival of the high-speed rail (HSR) have provided conditions for China's economic development that the industrialized countries did not have when the economy took off. This allows China to achieve a leapfrog development in many respects.

First, the market size has been expanded significantly. The era of mobile Internet makes it easy to communicate and trade, enabling local market to easily share market, knowledge and information with the rest of the world. Economic growth is no longer limited by the small local markets as in the past.

Second, fundamental changes have been brought to the traditional organizational model. The digital age offers the possibility of substantial innovation in organizational and business models. Many of the activities that previously needed to be organized within the firm can now be conveniently integrated through the global division of labor and accomplish many previously unimaginable tasks. Sharing taxi, sharing bicycles, and other innovative business models are such examples.

Third, the contents of development are changing. The digital era has spawned a large number of emerging services. With the new mobile Internet technology to meet people's needs for experience, emotion, culture, new supply of services will come into being. Some of these supplies are embodied on industrial products, while others are in new forms, or realize their values through roundabout business models. For example, the webcast economy, Facebook, WeChat and the business ecosystem it creates.

Fourth, the efficiency has been improved dramatically. The rapid growth of artificial intelligence will dramatically increase productivity and spawn a large number of new products and services. A survey by the Nihon Keizai Shimbun and the Financial Times showed that 34% (of 710 jobs) of all 820 occupations and 2,069 operations (jobs) could be replaced by robots. This means that in the future only a small amount of labor will be enough to meet the needs of the whole society.

According to McKincey (2017), China is already a leading country in the investment and application in digital technology, and has produced one-third of the "Unicorns" companies in the world. Its huge market makes it easier for quick commercialization of innovative digital business models. China's market has a large number of young consumers keen on digital technology. China's Internet companies are building a multi-industry, diversified digital ecosystem

that goes deep into every aspect of people's daily life. With the digital globalization progressing gradually, China is becoming the force that leads the global digital development through mergers and acquisitions, investment, export of new business models and technical cooperation.

For example, the penetration of mobile payment among Chinese Internet users is 68% in 2016. In 2016, China's mobile payment transactions related to personal consumption reached as much as US$790 billion, equivalent to 11 times of the U.S. rate. China ranks among the top 3 in the world for venture capital investment in some key digital technologies, including virtual reality, autonomous vehicles, 3D printing, robots, drones and artificial intelligence. In 2016, China's Internet users reached 731 million, surpassing the total number of Internet users in the EU and the United States. In China, 25% of Internet users access the Internet only through their mobile phones, compared with only 5% in the United States. Mobile end sales account for about 70% of China's total e-commerce sales, while the number is only 30% in the United States; China's mobile payment users accounted for about 68%, while the United States is only 15%. The number of people using APP to book taxi in Beijing is 8 times higher than that of New York.

At the same time, a large number of new green technologies are also emerging. By 2030, the turning points for lower cost of major green technologies than conventional technologies will come (for example, LBL, 2017; World Bank, 2016; McKinsey, 2009;). First, green energy, green transportation, green building, green materials will emerge. Second is the integrated use of green appropriate technologies based on traditional knowledge, such as the integrated application of ecological technologies in agriculture, construction, wetlands, sewage and eco-garbage disposal.

2.4 Two basic directions of green transformation

In any case, the world in 2020-2050 will be quite different. The above-mentioned historic changes have brought unprecedented opportunities for green development. These opportunities are reflected in two complementary directions. Anyway, the grasp of the opportunities of green development must be based on innovation in production and lifestyle. The traditional thinking on fossil energy featuring of industrial age cannot fully understand and recognize the opportunities in the digital green era. China's green transition will proceed along these two basic directions.

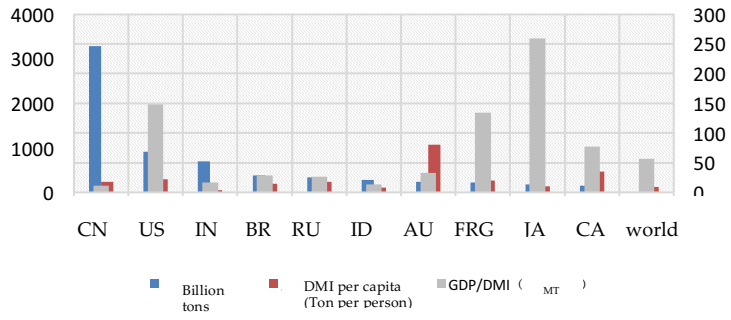
Transition Direction One: the greening of production mode, namely, using greener means to produce the existing content.

The new technology and organizational model should be adopted to green and upgrade the traditional sectors, greatly reduce the share of the traditional material factors in added value, and enhance the contribution of non-material factors such as knowledge and technology with high added value. The key to this transformation relies on the breakthrough of new technologies and application of mature technologies. This cost-effective up-gradation of traditional sectors will generate huge investments and become a driver for economic growth (LBL, 2017; REN21, 2017; World Bank, 2016; McKinsey, 2009).

According to the McKinsey Global Institute (2016), many traditional sectors in China are inefficient, over-dispersed and poorly serviced. Labor productivity in many industries is only 15-30% of the OECD average. By 2030, the efficiency gains in the traditional industries will provide a huge innovation of 5 trillion dollars. The OECD (2017) estimates also show that there is still much room for improvement in China's material resources productivity compared with OECD countries (Figure 6 and Figure 7).

Take the cost-effective green building upgrading technologies as example. According to the Paulson Institute (Mo, 2016) calculations, assuming that 50% of new public buildings and residential buildings (including 100% low-income security housing) during the 13th Five-Year Plan are green buildings and one-star green buildings account for 30%, Two-star green building 40%, three-star green building 30%, the total investment demand is at least RMB 224.8 billion. These can be financed in market.

Fig 6 Direct material resources investment (DMI) compared with economic growth 2010

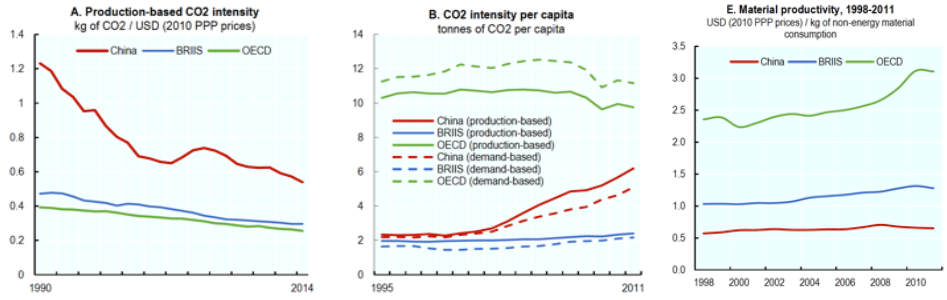


UNEP International Resources Panel.
Global material flows and resource productivity[R]UNEP, 2016

Transition Direction Two: the greening of lifestyle, that is, the production of green consumer content.

People's consumption attitudes and patterns have undergone three major changes, ranging from the thrifty agricultural era in the past to the consumer society characterized by stimulation of consumption in the industrial age (Goodwin, et al., 2008; Muke, 1984; Casser and Ryan, 1993). Now it is entering a new consumption model for the green era. As incomes rise and the green concept being widely accepted, and the popularity of mobile Internet technologies, many new green services that previously didn't exist in the industrialized countries will emerge. Under this background, the concepts, contents and pattern of consumption will be changing. The consumer now concerns for the environment, and experiential consumption become important new trends (Boven, 2005).

Fig 7 Carbon and material resource productivity: China's comparison with OECD and BRICS countries



Source: OECD (2017)

These new supplies are becoming an important source of green growth. According to China Consumption Trend (MEC, 2014), Chinese consumer behavior is changing rapidly and fundamentally. As the Chinese get richer, they will be more focused on spiritual consumption and giving back to society, and will be more environmentally friendly. These changes in consumer psychology are reflected in changes in buying habits. More Yoga and fitness services are such examples. Chinese consumers pay more and more attention to things other than material products. Eighty-four percent of survey respondents said they like to go shopping in a place with ambient atmosphere.

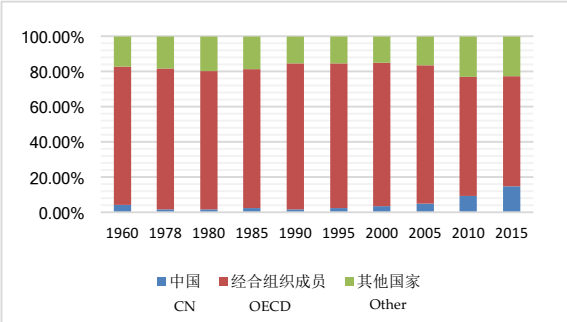
Section 3 The Global Significance of China's Green Transformation

3.1 Build a community of common destiny

Global green transformation is a prerequisite for the sustainable development of mankind and a precondition for building a community of common destiny. The traditional industrialization mode based on a large amount of material consumption established after the industrial revolution, although it has made great progress to mankind, is ultimately unsustainable. Due to the constrained capacity of global resources and environment, if all underdeveloped countries are committed to realizing their own modernization through this old mode, especially when the global population reaches 9 billion or more in 2050, the global crisis of resource and environment will be unavoidable.

This traditional model is destined to allow only a handful of people on earth to live with material abundance, but cannot make a globe with shared prosperity. Due to limited global resources and environmental constraints, the traditional industrialization mode inevitably forms a global division of labor structure featuring of "core countries and peripheral countries" A few core countries enjoy a rich material life at the top of the value chain, while peripheral countries are at the bottom of the value chain, becoming raw material suppliers and manufacturing base of the core countries and bearing more serious environmental consequences.

Fig 8 China's economic development (1960-20150)



Source: World Bank public database
https://data.worldbank.org

Only through the complete transformation of concepts, contents and mode of development and the decoupling of economic growth from the traditional

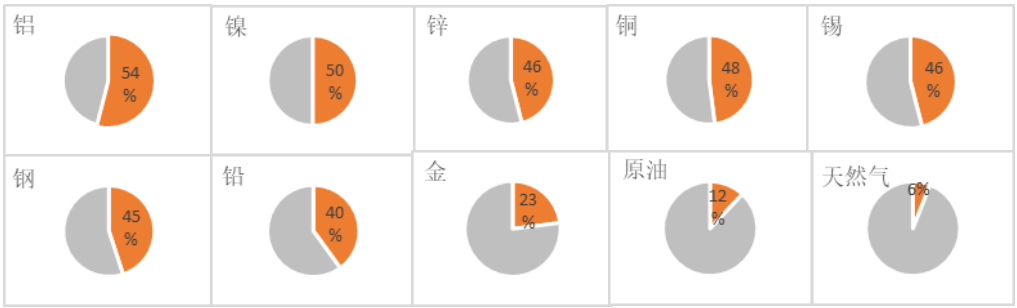
material resources as much as possible will it be feasible to get rid of the contradiction between resources and environmental constraints and the expansion of resource consumption, and to achieve global shared prosperity. For both developed and developing countries, green transformation is not an issue of whether or not, but an issue of how. Due to China's share in the global economy, its green transformation is of particular importance (Figure 8).

The biggest challenge facing the SDGs is that under the traditional development model, many of the 17 goals are difficult to balance. The simultaneous realization of these goals depends on profound changes in development model. As discussed in the previous sections of this report, under the traditional industrialization mode, economic growth will, to some extent, inevitably bring about the conflicts among environment, culture, society and governance. Only by systematically changing the development paradigm in the logic of ecological civilization can we hope to establish a compatible and even mutually reinforcing relationship between these goals.

3.2 The global significance of China's green transition

First is to form a win-win situation with the rest of the world. In the coming decade, even with an obvious decline in the growth rate, the annual increase of the Chinese economy will still be huge. The success of China's green transformation would not only reduce material resource consumption, but also provide huge green opportunities and market for other countries, so China's development will greatly benefit the whole world (Figure 9).

Fig 9 China's main consumption resource accounts 2014 (red)

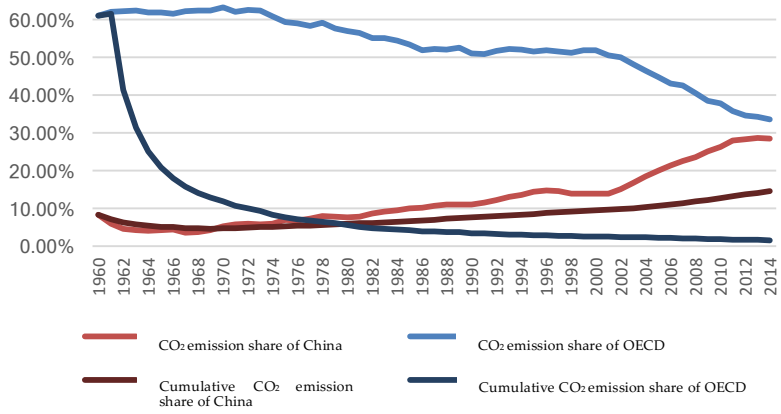


Note: from left to right in the first line are AI, Ni, Zn, Cu, Sn; in the second line are steel, Pb, gold, crude oil and natural gas.
Source: World Bureau of Metal Statistics
http://www.world-bureau.com/news.asp

Second, the success of China's green transformation plays an important role in resolving global environmental problems like climate change and in establishing an effective and sustainable global environmental governance system. Although it is not much difficult for China to meet its Intended Nationally Determined Contributions (INDC) emission mitigation targets, the reality is that even if all countries in the world achieve their emission reduction commitments, it still cannot meet the 2-degree temperature target. According to the IPCC Fifth Assessment Report (IPCC, 2014), at present rate of emission, the earth's temperature will rise by 3.7-4.8 degrees in 2100. Therefore, the current national commitments to reduce emissions is far from enough (UNEP, 2012; World Bank, 2012).

Third, if China can explore a new path of green development in the digital era, it will be of great reference to the development of less developed countries. The early experience of the development of industrialized countries would not be the only reference for economic development. Under the new development concept and new technology, less developed countries can realize their modernity through a leapfrog path of green development, so to avoid the traditional path of "pollute first, clean-up later" the industrialized countries took.

Fig 10 Annual emissions and cumulative emissions from China and the OECD account for the global share 1960-2014



Source: World Bank public database
https://data.worldbank.org

Fourth, as it becomes an engine of global green development, China will not only better play its important role commensurate with its own economic status in the world, but also this new concept of development and its soft power in the model of development will make a significant contribution to world development.

Chapter Two China Green Transformation: Prospects and Challenges

China's existing economic system, spatial pattern and infrastructure are largely the products of the traditional industrial era and need to be reshaped according to the inherent requirements of ecological civilization in the digital era. This chapter analyzes one by one the prospects and challenges of green transition in the fields of industry, agriculture, services, urban and rural areas, and infrastructure. The analysis of each field follows the clues: First, to summarize the achievements of the field and the high environmental costs behind it, and then to investigate the underlying reasons behind such high costs. On this basis, it points out the two complementary directions and potentials of green transformation in this area. Finally, the report identifies the challenges for the transition, which provides the basis for subsequent policy recommendations in chapter three.

Section 1 Reshape the Modern Green Economy: Industry, agriculture and Service

1.1 Reshape the modern green industrial system

1.1.1 The great achievements of China's industrialization and its costs

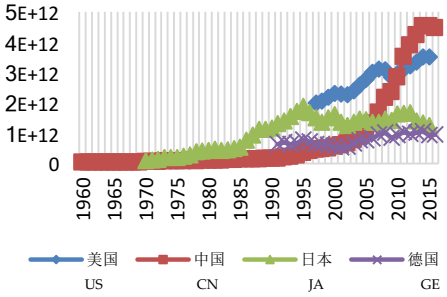
Since the Industrial Revolution, industrialization has become a synonym of economic development. The tremendous growth China made can also be attributed to rapid industrialization. In past decades, China has established a comprehensive industrial system from a backward, closed agricultural economy and has become the world factory and the world's largest manufacturing power.

In 2015, the value added of China's secondary industry was 28.02 trillion yuan, 47.26 times of the 1978 figure at comparable prices. From 1978 to 2015, employment in the secondary industry in China increased from 49.4 million to 226.9 million. In 2010, China overtook the United States as the number one manufacturing powerhouse and surpassed Germany to become the number

one export powerhouse. In 2014, the outputs of more than 220 kinds of industrial products produced in China ranked number one in the world, from low-tech products such as clothing, shoes and hats, toys and furniture to high-tech products such as automobiles, personal computers and mobile phones (NBS, 2017, figure 11,12).

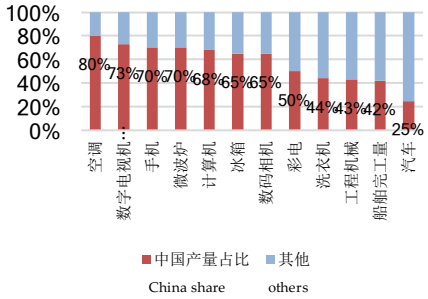
However, behind such a huge achievement is the high ecological and environmental costs. Industry is a major source of pollution in China, which is characterized by "three wastes", i.e. waste water, waste gas and waste material (Figure 13). Emissions of untreated water, gas, slag and other wastes in industrial production have seriously damaged the ecological balance and natural resources, causing great damage to agricultural production, industrial production itself and public health. Industrial "three wastes" and urban life and other external pollution spread to agriculture and rural areas. Cadmium, mercury, arsenic and other heavy metals continue to infiltrate the origin of agricultural products.

Fig 11 Industrial added value of major countries, 1960-2014 (current price $)



Source: World Bank public database https://data.worldbank.org

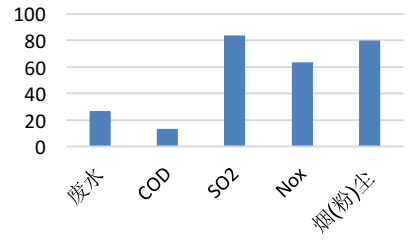
Fig 12 China's major industrial output accounts for the world's share of 2010



Note: from left to right, air-conditioner, STB box, cell phone, microwave oven, CP, refrigerator, Digital-camera, TV, washer, engineering machinery, ship, car

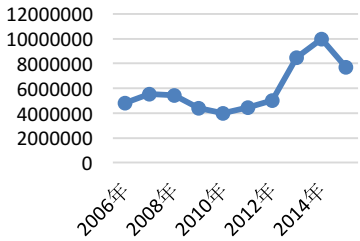
Source: China National Bureau of Statistics http://data.stats.gov.cn

Fig 13 The proportion of major industrial pollutants of China in 2015 (%)



Note: from left to right, waste water, COD, SO_2, NO_x, dust
Source: Ministry of Environmental Protection 2015 Annual Report on Environmental Statistics.

Fig 14 China's industrial pollution control investment（10 thousand yuan）



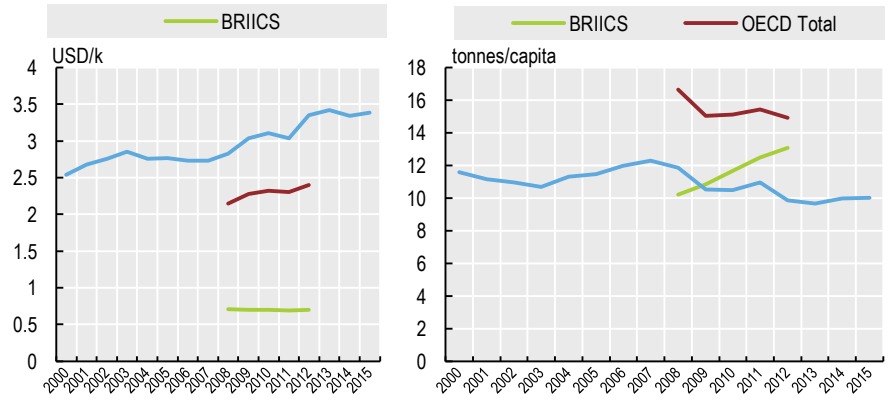
Source: National Bureau of Statistics.

Therefore, behind the seemingly cheap industrial products is a huge environmental external costs, hidden costs, long-term costs and other opportunities cost for development due to pollution. It spends a lot of money to control and clean industrial pollution (Figure 14). Taking into account these costs, the loss of many industrial activities often outweighs the benefits. As a factory in the world, China provides cheap manufactured goods worldwide, but its high environmental cost is borne by itself.

1.1.2 Reflect the traditional mode of industrialization: Why high pollution?

However, the pollution brought by the traditional industrialization is not only a simple question of raising efficiency and enhancing the environmental protection, but there are deeper reasons behind it. That is, the logic of traditional industrialization is largely conflicting with the logic of ecological civilization. The traditional mode of development takes industrialization as the core, while the high productivity of material products of industrialization requires enough market demand based on high-material consumption. Not only the industrialized process itself will bring pollution, but also its tentacles continue to invade the ecosystem system to bring systematic damage to the ecological environment.

Fig 15 Material consumption remains high despite rising productivity



Note: Aggregates shown here are based on estimates to fill missing values
Source: Figure 3.2 in OECD (2017)

This means that even a substantial increase in the efficiency and environmental standards in China's industrial production is only necessary and not sufficient for industrial green transition. As long as economic growth relies on overconsumption of industrial material products, the increase of efficiency will increase the total volume of material production and consumption, and consequently increase the environmental footprint (see Figure 15). To a large extent, this is determined by the inherent logic of the traditional industrialization model. Traditional industrial civilization must obey the logic of ecological civilization in order to avoid crises and gain sustainable vitality.

1.1.3 Direction and potential of Industrial green transition

1) Two complementary transition directions

Transition Direction One: the greening of industrial production processes, that is, the upgrading of existing industrial systems to produce the same content in a greener way. Prior to 2035, the focus of the green industrial transformation will mainly be to catch up with the global industry-leading level. Specifically, there are the following ways.

- Technology and management upgrades. Improve the green level of the production process. These need to be accomplished through the use of a new generation of information network technologies, new energy technologies, clean technology restructure, contract energy management, new materials, industrial design, flexible manufacturing and industry 4.0 to reduce the energy, environmental and material consumption of per unit industrial products.

- Organizational model upgrade. The traditional massively homogeneous mass manufacturing has its advantages. However, the way that decentralized small manufacturing units share a unified digital platform such as design, development and promotion to achieve decentralized manufacturing is also rapidly emerging.

Judging from China's carbon productivity and resource productivity, China not only has a big gap with the global advanced level, but also has a gap with the BRICS countries. To produce same industrial products, China's industrial sector consumes more resources and energy and generates a higher environmental footprint. Moreover, many emerging green technologies have matured and China can take the lead in commercial applications.

However, a reduction in the environmental footprint of industrial products per unit does not necessarily result in an overall improvement in the environment, as efficiency gains may be offset by increases in domestic industrial consumption or expansion in international trade (Gillingham, Rapson, and Wagner, 2016). So the transition in the second direction below is especially important.

Transition direction two: to provide new types of green consumer products, and to make industrial products the physical carriers of a large number of emerging service in order to enhance the inherent quality and added value of industrial products.

- Implantation of more customized and experiential services beyond physical functions into industrial products to enhance product quality and added value. The use of a new generation of information network technology and big data resources continuously improve the flexibility of the production process, from a single large-scale manufacturing, diversified, customized manufacturing.

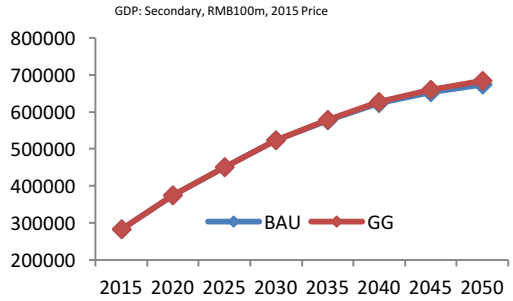
- From manufacturing to service-oriented manufacturing. Through the business model innovation and format innovation, vigorously promote the "product + service" consumption model. Encourage consumers from the past to buy physical products to buy the service functions of products, so to reduce the demand for physical products.

- Traditional craftsmanship rejuvenation. Intangible resources, including culture and ecological environment, could be implanted into industrial products and become an important source of high added value for industrial products. This means that a large number of traditional handicrafts can also be revitalized on the basis of modern technology.

2) Potential of industrial green transition: 2020-2050

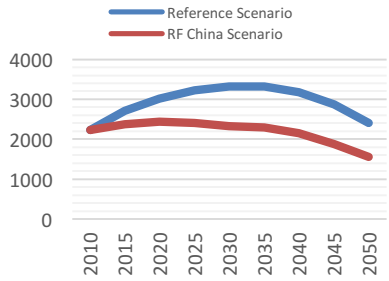
The potential by 2035 is based on "what can be done", that is, using the relevant plans made by Chinese government as well as international advanced technology and environmental standards as a reference for the transition. For the period 2035-2050, we refer to "must be" as reference reversed by the standards that must be met to achieve global sustainability goals. 2020-2050, China's green industrial transition has the potential to create higher value-added, consume less resources.

Fig 16 China's industrial transformation potential 2020-2050



Source: DRC Green Team.

Fig 17 China's industrial primary energy use (Mtce):2010-2050



Source：ERI, LBNL and RMI (2016)

First, the quality of the industry and the added value increase. After a period of transitional transition, the added value of green industry will be higher than the BAU scenario (Figure 16).

Second, the total consumption of green industry in material, energy and emissions will be significantly lower than in the BAU scenario.

The results of the DRC green team are similar to those of the Reinventing Fire (ERI, LBNL, and RMI, 2016) task force (Figure 17), while the latter is more in-depth and detailed. According to RF calculations, the primary energy consumption in 2050 is 1.5 Btce.

1.1.4. The challenge of industrial green transformation

However, it is by no means easy to realize the above potential of green transition, which depends on overcoming the following challenges:

●Loss of greater transition benefits due to high short-term implementation costs. The internalization of external environmental costs will significantly reduce the various costs of social burdens, thereby enhancing the quality of

economic growth. However, internalizing these external costs involves short-term implementation costs. Under such circumstances, the government may give up the greater benefits that the transition can bring because of the high short-term implementation costs, especially when such benefits have not been realized by many people or need new mechanism to realize it. This requires the vision of policymakers and strong government capacity to execute.

● Environment Protection and material resources limiting may be not restrict enough. The industrial expansion centered on the input of material factors and the output of material products has always been regarded as the core of economic growth. If countries concerned about their growth goals and did not impose strict restrictions on the consumption of high-resource-consuming industrial products, green technology may have a rebound effect. It will increase industrial consumption instead of reducing industrial environmental footprint.

● High transition costs due to sunk costs and path dependencies. Industry is a highly capital-intensive industry. Even if traditional enterprises have new, more efficient and cheaper green technologies that does not mean that these new technologies will be applied immediately, but must wait until the early investment is returned.

● Mechanism issues. Due to the lack of related system design, some green technologies are difficult to apply and popularize so that they fall into non-green trap and green jump is hard to happen. A typical example is contract energy management, which involves difficulty as it relates to financing mechanisms, contract enforcement mechanisms, and so on.

● Without a flexible market pricing mechanism, the increase in business costs associated with raising environmental standards can be hard to pass on, reducing corporate profits. This change is more difficult if the environmental performance standards in different regions are not uniform.

● National and global coordination difficulties. The effectiveness of environmental standards depends on national and global synergies. The adoption of high environmental standards in individual regions or countries will make investment flowing to countries with low environmental standards, resulting in unfair competition. Under the GDP-oriented system and the existing taxation system, the incentive of local governments in environmental protection has also been affected.

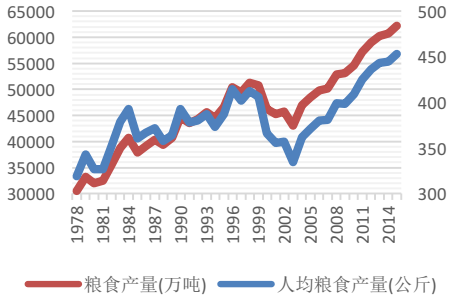
1.2 Reshape the modern green agricultural system

1.2.1 The great achievements of China's agriculture and its problems

The great achievements made by China in agriculture are manifested in many aspects. However, one sentence can be simply used to conclude that China, by using 7% of the world's arable land, feeds 20% of the world's population. From 1949 to 2016, the grain output in China increased from 113 million tons to 616 million tons, and the per capita grain output increased from 0.2 ton to 0.45 ton, while the population in the same period increased from 540 million to 1,375 million (Figure 18; NBS, 2016).

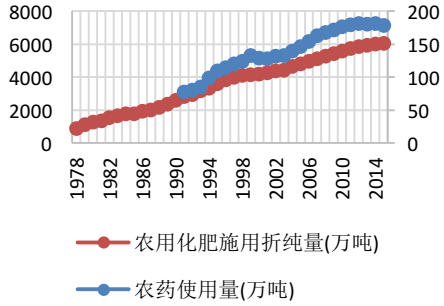
At the same time, however, China's agriculture has quickly embarked on a path of industrial agriculture and chemical agriculture, from the traditional ecological agriculture of the past (Figure 19). China's agriculture consumes more than 30% of the world's total chemical fertilizers, and the amount of chemical fertilizer applied per unit area is more than three times the world average (Sattari et al., 2014; Lu and Tian, 2017). Figure 20 shows that BRICS countries, including China, use twice as much per unit area as OECD countries. Due to the heavy dependence on chemical fertilizers, pesticides, herbicides, hormones, antibiotics and agriculture, huge pollution has resulted in severe pollution of lakes, rivers, groundwater and soils, biodiversity loss and outstanding food safety issues. Obviously, such an approach to agricultural development is not sustainable.

Fig 18 China's Grain Output and Per Capita Grain Output 1978-2015



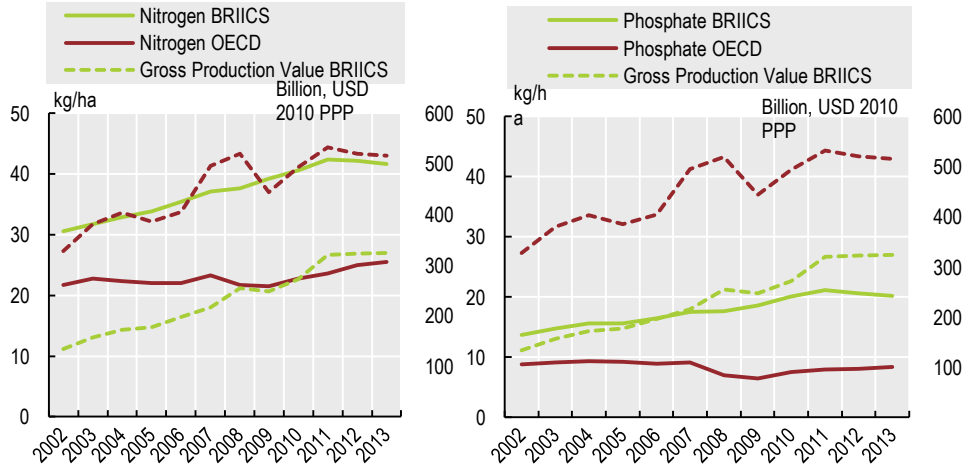
Note: legend from up is China's Grain Output, Per Capita Grain Output
Source: China National Bureau of Statistics. http://data.stats.gov.cn

Fig 19 China Fertilizer and Pesticide Usage 1978-2015



Note: legend from up is China Fertilizer usage, Pesticide Usage
Source: China National Bureau of Statistics http://data.stats.gov.cn

Fig 20 BRIICS consume almost twice the level of fertilizers per agricultural area as OECD



Note: Consumption of nutrients from fertilizers is expressed in kg/ha of agricultural area (left axis). Crop production value is expressed in USD using 2010 prices and PPPs (right axis). OECD excludes the Czech Republic.
Source: Figure 4.3, OECD (2017) made based on FAO (2017), FAOSTAT (database). OECD (2016b), "OECD economic outlook No. 100 (edition 2016/2)", OECD Economic Outlook: Statistics and Projections (database).
DOI: http://dx.doi.org/10.1787/7fa317bf-en (accessed in January 2017).

1.2.2 Reflect on modern agriculture: the root cause of the agricultural pollution and its outlet

Green transformation requires a profound reflection on the so-called modern agriculture. The problem of modern agricultural pollution is due in large part to the result of restructuring agro-ecosystems with the logic of industrialization. Industrial agriculture, which emerged after World War II, is characterized by factory-type monoculture and confined animal feeding operations (CAFO), relying on extensive use of chemical fertilizers, pesticides, herbicides, antibiotics, growth hormone.

Of course, industrial agriculture has its advantages, which in many cases have led to an increase in agricultural output and in labor productivity, but also posed unsustainable serious environmental problems. In fact, industrial agriculture costs more than eco-agriculture. The former's hidden costs include: a large number of agricultural subsidies, environmental pollution costs, the loss of biodiversity, reduction of the value of rural communities, the cost of product quality, human health hazards, and so on.

The root cause of agricultural pollution lies in the fact that agriculture and industry have different logics. Agriculture is an integral part of the overall

ecosystem. It has close and complex interdependence with other elements of the ecosystem. Many of these elements are not readily observable as the industrial physical world; By using large-scale single production with the industrial logic to produce some of the "valuable" elements of the ecosystem alone, it will bring about the collapse of agro-ecosystems and the corresponding environmental and social consequences.

Before fossil oil farming, China actually had very good eco-agriculture in the world (Kim, 2011) [4]. Recognizing the enormous costs and harms of chemical agriculture, reducing the amount of chemical fertilizers used in agriculture has become a consensus and policy action in China. The Chinese government has formulated the "National Plan for Sustainable Agricultural Development (2015-2030)" and the "Overall Plan for the Management of Prominent Issues in Agricultural Environment (2014-2018)" and the objective of pesticide reduction. However, without changing the conventional methods of agricultural production, the goal of reducing the amount of chemical fertilizers and pesticides can be achieved by either sacrificing output or increasing costs. The key to achieving this goal is to shift chemical agriculture to eco-agriculture (IPES-Food. 2016; Kuepper, 2010; Raffensperger and Myers, 2004).

Due to the dominance of industrial agriculture and chemical agriculture, there is a great deal of misunderstanding and unwitting distortion of eco-organic agriculture (see Kimbrell ed. 2002). The University of Michigan research team (Badgley, et al., 2007) based its yield database for the world's major crops in 293 cases, and the meta-analysis of the yield studies of organic agriculture by Seufert et al (2012) show that although organic agriculture generally yields less than conventional chemical agriculture, it depends on contexts such as management, variety and location. In developing countries, organic agriculture often yields more. Moreover, the combined output of mono crop of industrialized agriculture and multi-crops organic agriculture could not be easily compared in many cases.

[4] At the beginning of the 20th century, the American agronomist and director of the Department of Soil Management of the Ministry of Agriculture, F. H. King, inspected the ancient farming system in East Asia and wrote " Farmers of Forty Centuries of Permanent Agriculture in China, Korea and Japan) praised the traditional ecological agriculture in East Asia and considered Eastern farming the best agriculture in the world. The oriental farmers are diligent and intelligent biologists (King, 1911).

Organic agriculture is only part of ecological agriculture. The transformation of ecological agriculture will generate a great deal of value for agro-ecological services and will generate a great deal of non-agricultural value (IPES-Food, 2016; Altieri, 1995; Halberg, Niels and Müller, Adrian, 2013). In particular, in the digital age, innovations in digital technologies and business models can also embody a variety of new services in agricultural products to increase the added value, and enhance the value of the community's ecological environment.

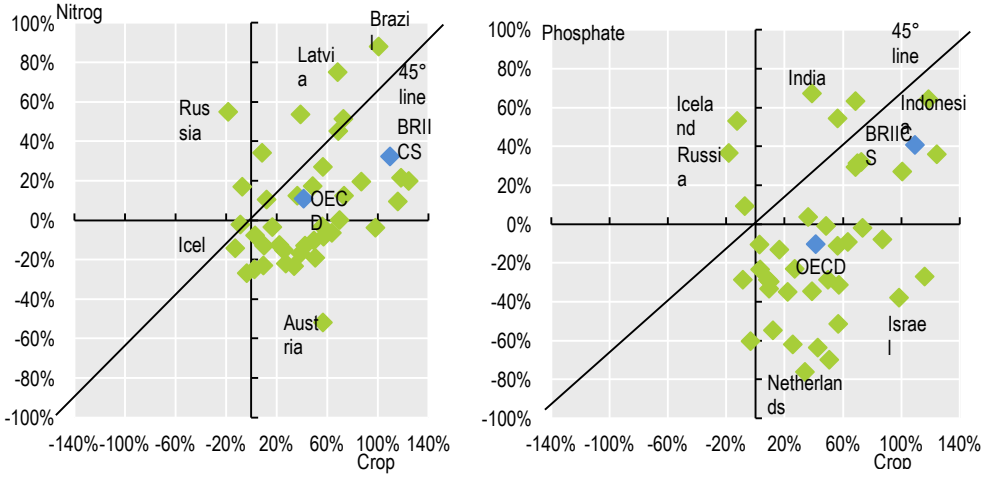
Therefore, when discussing agricultural transition, we must go beyond the narrow agricultural output perspective. As a fundamental industry, the chain benefits that eco-agriculture brings are not just about yield. When discussing the transformation of ecological agriculture, it does not mean to simply return to the traditional agriculture in the past, but make full use of modern technologies including the Internet and Internet of Things under the logic of ecological civilization to substantially raise the value of agriculture and its derivatives.

1.2.3 The potential of green transition of China's agricultural: 2020-2050

Industrial agriculture and eco-agriculture essentially represent two different development paths. Both have different logic and each has advantages and disadvantages. The transition of green agriculture in China is not to choose between industrial agriculture and ecological agriculture, but to make full use of these two complementary paths. Chinese government attaches great importance to agricultural green transformation.

The first direction is to upgrade the existing dominant chemical agriculture through new technologies, such as precision agriculture and facility agriculture, significantly to reduce resources, pesticide and chemical fertilizer use, to reduce pollution and to increase efficiency. Given that most of the agricultural sector has now been industrialized, this path is a "convenient" but costly solution. Experience from OECD countries shows that both fertilizer reduction and increased agricultural production can be balanced to some extent (Figure 21).

Fig 21 National fertilizer use and production decoupling conditions

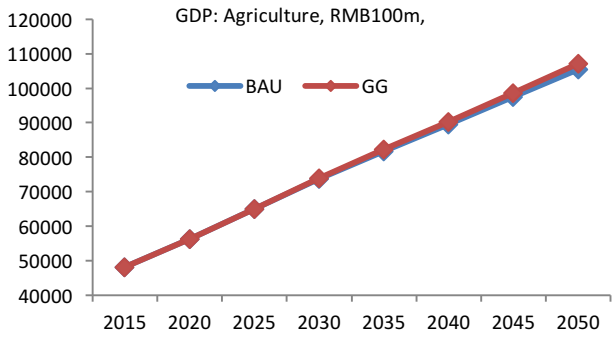


Note: Consumption of commercial fertilizers is expressed in kg/ha of agricultural area. Crop production value is expressed in USD using 2010 prices and PPPs. OECD excludes the Czech Republic
Source: Figure 4.2, OECD (2017).

The second direction is to use the principle of ecology to fully release the power of nature so as to increase the yield, quality and ecological effect with low cost. The value of ecological agriculture transformation is not only limited to agricultural output, but also greatly increases the value of agricultural ecological services, laying the foundation for more non-agricultural economic activities. For example, the agricultural aesthetic value, leisure value, sports value, entertainment value, cultural value, health value. Obviously, depending on the chemical agriculture chemical fertilizers, it is difficult to have these values.

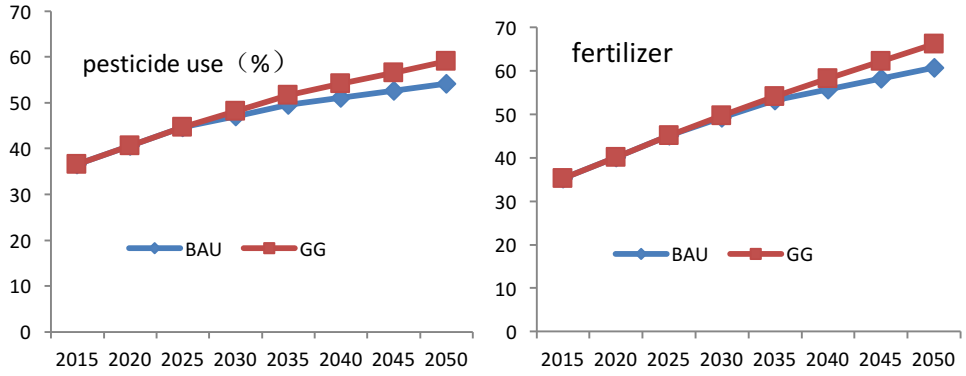
Based on these two directions, the research team investigates the potential for green agriculture transformation from 2020 to 2050. According to the Chinese government's green agriculture planning and international best practices, the BAU scenario for 2050 is set at the lower limit of chemical pesticide utilization rates in developed countries while the green transformation scenario is set at the upper limit in 2050. Scenarios show that agricultural production in the green transition has remained generally stable, but value added has been higher than the BAU, as the quality of agricultural products will be improved and more and more services (not only selling agricultural products but also selling services) will be embedded. At the same time, pesticide and fertilizer use less than BAU.

Fig 22 Impact of China's Green Agriculture Transformation on Output Value: 2020-2050



Source: Made based on the data of Ministry of Agriculture

Fig 23 Pesticide and fertilizer utilization under green transition（a,b）:2020-2050



Note: In BAU scenario, the ratio of pesticide and fertilizer utilization will reach the lower limit of the developed countries around 2050, while in green agriculture scenario, the ratio of pesticide and fertilizer utilization will reach the upper limit of the developed countries around 2050. Although the ratio of agriculture added value to GDP declines, yet the amount of added value will be higher in green agriculture scenario than that of BAU scenario.
Source: Made based on the data of Ministry of Agriculture

1.2.4 Challenges of Green Agriculture Transformation

● Unfair competition. Since mainstream agriculture has been transformed by chemical agriculture, the existing agricultural system and policies are also mainly based on chemical agriculture. For example, peasants buying pesticides and fertilizers can enjoy state subsidies for agriculture, while the non-point source pollution caused by chemical agriculture requires governments to invest heavily to clean-up. However, good ecological services provided by green eco-agriculture cannot be properly compensated (except returning farmland to forests and grass).

● Difficulties of systematic change. Eco-organic agricultural products need to be differentiated in the market from traditional industrialized agricultural products to achieve their high value. However, the existing dominant

agricultural products storage, processing, marketing, business model and other systems are organized based on industrial method. Ecological agriculture needs a new system. Therefore, the transformation of eco-agriculture is not only a matter of individual enterprises and / or individual products, but a systematic transformation.

- Since the per capita arable land of the farmer is little, the main income of many farmers comes from revenue working in the cities. Even though the transformation of ecological agriculture has obviously increased its agricultural income, its share in farmer's income has remained relatively low. Therefore, peasants lack sufficient enthusiasm for the eco-agricultural transformation. This requires a new way of organizing.

- The high cost of new technologies. The transition in the first direction depends on high technology and high investment. This involves a series of issues such as legislation, implementation costs, organization methods and markets. In particular, it is more difficult to find ways to have the individual farmers to reduce the use of chemicals by increasing the costs.

1.3 Green transition of modern service

The existing services, from content and organizational models, are to a large extent the product of the industrial age. Services are largely for industrial production, while traditional industrial production is an important source of environmental problems. If the content and mode of overall economic development are not to be transformed, the expansion of service industries will often lead to more consumption of industrial products and material resources, which will not necessarily result in a green transformation of the overall economy. Under the digital age and the concept of green development, changes in the content of development will be more reflected in emerging service industries. Therefore, the service industry will have more room for development in terms of scale and breadth.

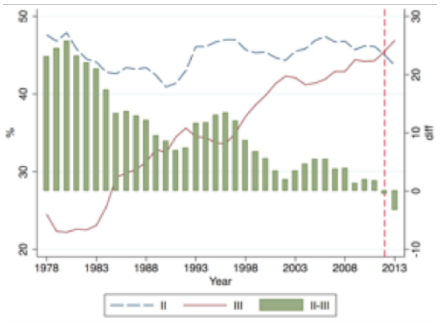
1.3.1 Achievements of China's service sector (tertiary industry) and problems

Since 2013, China's service sector has surpassed that of industry in its GDP and China's economy has entered the era of so-called service economy. In 2016, China's tertiary sector accounted for 51.6% of GDP, its contribution to GDP

growth reached 58.2%, and service sector's influence on China's long-term economic growth was also growing (Figure 24). From the three industries' employment structure, China's service industry is becoming the largest "employer." At the end of 2016, the number of employment in the tertiary industry in China reached 337.57 million, accounting for 43.5% of all employed people, 14.7 percentage points higher than that of the secondary industry (NBS, 2016).

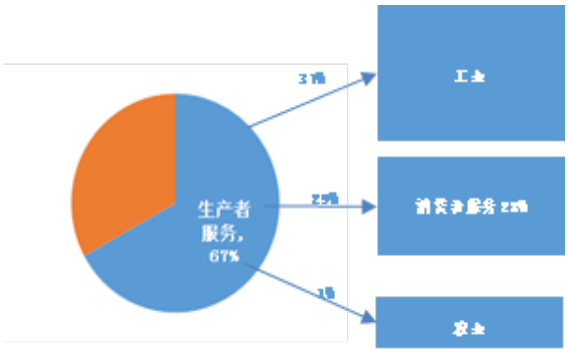
In services, 67% are producer services and 28% are consumer services. In the productive services, 55% in turn serve secondary industries (Figure 25).

Fig 24 China's secondary and tertiary industries' a share of GDP (%)



Source: National Bureau of Statistics

Fig 25 The Formation and Orientation of China 's Service Industry



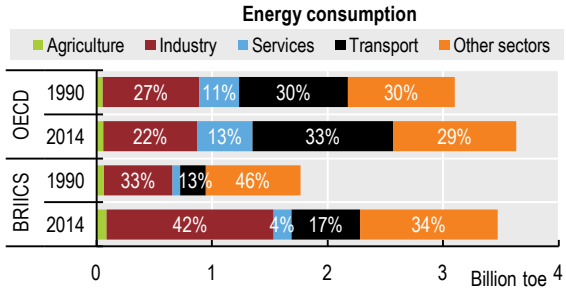
Note: Service industry includes consumer and producer services, and another 5% goes to investment service.
Source: figures made from input-output tables of China 2012

It is generally believed that the service industry consumes less resources and environment capacity than the primary and secondary industries and that the development of the service industry is generally considered to be an effective solution to the environmental crisis. Intuitively, the developed countries have also seen a substantial improvement in their environment after their economic structure entered the service economy. According to estimates by Wang et al. (2013), in 1995-2010, China's service industry consumed 962 126.37 × 104 KJ of energy, accounting for 10.18% of the total energy consumption in China. The cumulative total of CO_2 emissions was as high as 853 197.55 × 104 t, accounting for 9.53% of the total cumulative amount of China's CO_2 emissions.

However, structural upgrading brought by the service sector does not necessarily mean green transformation. First, not all service industries are low-

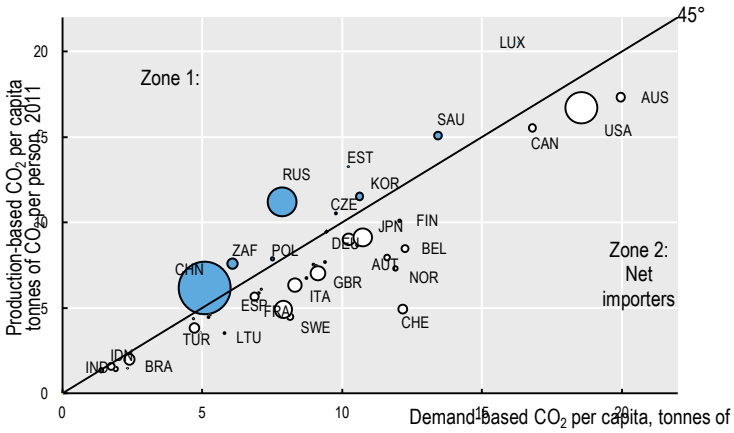
carbon industries. Construction operations, transportation, together with industry, are the three major "energy consumers" in China. The same is true for OECD countries (Figure 26). Second, under the traditional industrialization model, the structural changes brought about by service expansion and the improvement of environmental and resource efficiency per unit do not necessarily mean the decline of the overall environmental footprint nor the green transformation. It can also lead to an increase of overall environmental footprint. This damage is often borne by other countries through the import of products (Figure 27; OECD, 2017). For example, for Annex 1 countries (AN1) with service industries as their main body, although their productive emissions are decreasing, the embedded carbon emissions in their imports are on the increase, resulting in increase of their total carbon emissions (Peters, Minx, Weber, and Edenhofer, 2011).

Fig 26 OECD and BRIC countries energy increase for each industry



Source: Figure 2.1, OECD (2017)

Fig 27 Most OECD are net CO_2 importers



Note: The size of the bubble represents the level of net exports of embodied CO_2. White bubbles indicate negative values of net exports (i.e. net imports). The 45-degree line shows equal emissions of production- and demand-based CO_2

Sources: Figure 1.5, in OECD (2017)

1.3.2 Re-recognize the service industry

First, under the concept of green development, the value and potential of emerging services are much greater than those in the industrial age. The fundamental purpose of economic development is to meet people's all-round needs. However, the material needs that are emphasized by the traditional industrialization model are only part of people's needs. Activities to satisfy the non-material needs of people can create value and are an important source of green growth. It involves the question about the theory of value in economics. For example, based on the experiential needs in the digital age emerged social products, like Facebook and WeChat.

Second, emerging Internet-based services can have much higher productivity than industrial production. Due to the non-rival nature of many service activities, especially the emerging service industries such as online entertainment, public art, telemedicine and MOOC education, Internet and cultural activities, the production efficiency is much higher than that of traditional industries, which is also sustainable.

Third, the upgrading traditional service industries through the new business model or the formation of new service industries can greatly improve resource efficiency. For example, the sharing economy represented by Mobike, OFO, Uber and AirBNB, can greatly increase the utilization of stock resources and reduce the pressure on natural resources.

In short, emerging services can not only be an important source of economic growth, but also have higher productivity and are more sustainable. In the future, the development of emerging service industry in the digital age does not necessarily have to wait until the economic development reaches a certain stage. This means that with the help of such conditions as the Internet and the Internet of Things, the underdeveloped countries are likely to have a leapfrog economic development.

1.3.3 Potential for China's service transition: 2020-2050

1) Two Complementary Directions for Green Transition of Service Industry

The first transition direction: Transition and upgrading of the existing service industry, including producer services and consumer services. Much of traditional service is difficult to achieve both economy of scale and increasing returns due to the need for face-to-face production and consumption, and has the difficulty in storage and long distance supply (low tradability), high degree

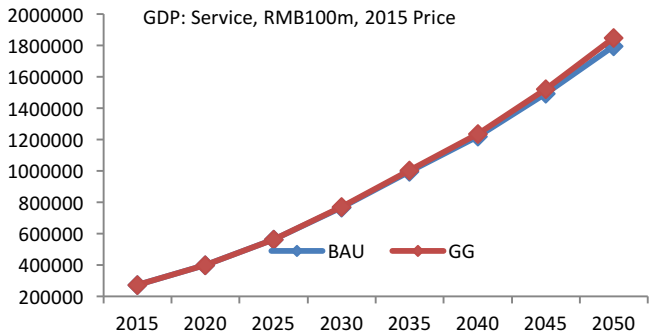
of personalization (non-standardization). So the productivity is lower. However, the development of information technology is significantly improving the organizational structure and efficiency of traditional service industries. Using the Internet outsourcing services, mobile payment, e-commerce, online shopping, etc., a large number of services can be provided at low cost for long distance, the efficiency of the service industry has great room for improvement.

The second transition direction: fostering emerging services and formats, especially experience services based on the Internet.

A variety of services based on the ecological environment, culture, customized needs, combined with the Internet, can be derived from many new service products. In particular, with the influence of new technologies such as the Internet, service application and innovation based on big data, cloud computing and the Internet of Things have become increasingly active. For example, the sharing economy is applied in traditional industries such as catering and house services. New services such as online shopping, distant education, online medical services and digital house services are on the rise. A variety of services based on the environment, culture, retirement, sports, tourism and customized needs, combined with the Internet, will stimulate innovation.

Through the upgrading and transformation of producer services, implanting experiential services and customized services in the material products so that the industrial products are no longer limited to providing physical functions. This can improve the quality and added value of the material products.

Fig 28 The transformation potential of China's modern green service industry：2020-2050



Source: made by DRC green team.

1.3.4 Challenges in green transition of service industry

● Since the existing service industry is largely a product of the industrial age, the green transformation of the service sector depends to a large extent on the green transformation of industry. Both must be coordinated to promote.

● Emerging services require new infrastructure and public goods, unlike traditional services. For example, digital infrastructure, Internet of Things, ecological environment protection, cultural protection, landscape design and other requirements. The existing statistical system is also established in the industrial age and it is difficult to reflect the development of the service industry, especially the emerging services.

● Many of the regulatory systems established in the industrial age have fallen short of the requirements of emerging services and business model innovation. With the advent of the digital age, such conflicts will be further exposed.

● The current system and policies, especially the tax system, are largely aimed at promoting manufacturing economy, not conducive to the development of the service, to the efficiency of service industries and the development of new service industries in the future.

● The institutional barriers and institutional costs in some service industries are still high, resulting in the shortage of many monopolistic services in China, such as medical care, education and pension.

Section 2 Reshape the Spatial Pattern: New Urban, Rural and Urban-Rural Relations

The existing model of urbanization and the relationship between urban and rural areas are to a large extent the product of the traditional industrial era. The concentration of population in urban industrial sectors has greatly accelerated the process of industrialization, formed a modern social structure based on industrial civilization, and formed the basic urban-rural division of labor pattern of "city-industry, rural-agriculture." With the advent of the digital era and the era of green development, as well as the popularization of the rapid transit system, the content and organizational model of development are undergoing profound changes. The patterns of urbanization, the functions of rural areas and the traditional urban-rural division of labor will also undergo profound changes.

2.1 Reshape the green town pattern

Since modern economic activities occur mainly in urban areas, most of the environmental problems also originate in cities. How cities are made greener is regarded as an important solution to environmental problems. When discussing green urbanization, it is natural for people to think of existing cities and towns as the logical starting point for discussing issues. For example, the concept of compact city, sponge city. However, thinking about the transformation of green urbanization needs to start with the logical starting point for why cities emerge, rather than starting from the existing cities.

2.1.1 The rapid development of China's urbanization and its existing problems

In 1949, only 10.6% of China's population lived in cities. By 2016, China's urbanization level reached 57.4% (NBS, 2017). According to the experience of industrialized countries, it is expected that by 2035, about 72% of China's population will live in cities and towns. In 2050, this proportion will rise to about 80% (Figure 29).

Urbanization, brought about by rapid industrialization, has also brought about various "urban disease", including huge environmental costs -

● Air pollution: mainly includes vehicle exhaust pollution, industrial production emissions pollution, waste incineration pollution;

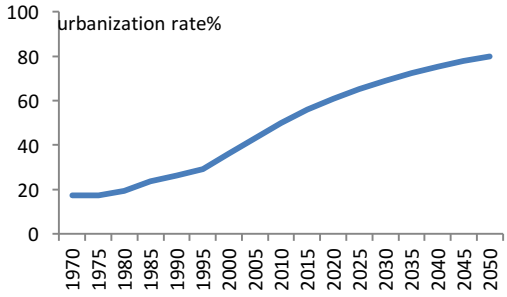
●Water Pollution: surface water of rivers and lakes, groundwater pollution, etc.

● Noise pollution: building construction noise pollution; traffic noise pollution; industrial enterprise noise emission pollution; living noise emission pollution;

● Solid waste pollution: Mainly construction waste, domestic waste pollution; white plastic pollution and so on.

● Extensive land use.

Fig 29 Rapid urbanization in China 1970-2050



Source：DRC Green team model

In addition, urbanization is accompanied by high social and cultural costs. On the one hand, big cities fall into the predicament of being "hard to buy a house, harder in education, harder in medical treatment," and "high income and low wellbeing" have become outstanding problems. At the same time, migrant workers can hardly truly integrate into the cities. On the other hand, urban issues and rural issues have become two side of one coin. The original rural social fabric has been hit by large-scale urbanization. The issue of "three rural issues" has become a serious problem with a large number of hollow villages, left-behind children and the elderly, so that the 19th National Congress of CPC put the "revitalization of the countryside" as a major strategy.

2.1.2 Rethinking Urbanization: Industrial Age Vs. Digital Green Age

1) Logical starting point for green urbanization: Why cities?

The current pattern of urbanization is mainly the outcome of development mode based on the production and consumption of industrial products

established since the industrial revolution. As the human society enters the digital age, the entire development concept and content are undergoing dramatic changes. The pattern of urbanization in the future will also be very different.

The logical starting point for discussing green urbanization should be why there is a city. The reason why people concentrate from scattered rural areas to cities and towns is to seek higher wellbeing, and the physical concentration of population into the cities can substantially increase their material productivity.

The advantages of the city are: First, it can reduce transaction costs. When the production of various parts of an industry is relatively concentrated in the cities, it is easier for division of labor and collaboration than to be scattered in different parts of the country. At the same time, population concentration has also expanded the market. Second, it can facilitate the provision of infrastructure and government public services. Concentration will greatly improve efficiency and save costs of tap water, electricity, gas, water, communications and other public facilities. Thirdly, the concentration of population in the cities can facilitate the exchange of ideas, which is conducive to the emergence and spread of knowledge.

In the industrial age, urbanization was especially important for industrialization because economic development was based on the production and consumption of industrial material wealth. The concentration of population in urban industrial departments has greatly accelerated the process of industrialization and formed a modern social structure based on industrial civilization. It also formed a geographically divided pattern of "city-industry, rural-agriculture" (Yang 1991; Yang and Rice, 1994; Henderson, 1974; Fujita, 1989; Fujita and Krugman, 1995).

Therefore, there are three key factors determining the mode of urbanization: First, transaction efficiency; second, the supply of public facilities and public services; Third, the content of development. The changes of these three factors determine the future direction of the city. From the industrial era to the digital green era, all three of these factors are undergoing substantive changes.

First, the efficiency of the transaction has risen dramatically. The market does not need to be so dependent on the physical concentration of factors of production and markets as in the industrial age. With the advent of mobile Internet technology, the digital age and the fast transport system, the traditional concept of time and space is undergoing dramatic changes, and

some works that need to be done in the cities can now be done in the countryside.

Second, changes in technological conditions have made it possible for some public facilities and services that previously relied on centralized supply to be decentralized. For example, heating, sewage treatment, distributed energy, waste treatment, etc., in many cases can be shifted from a centralized supply to distributed supply. This means that high quality of life can be achieved at low cost in small towns and villages. In the digital age, many government services are also available through the digital platform.

Third, and more importantly, changes in the content of development. With the advent of the digital age and the change in the concept of development, people have higher demands on the quality of the environment and the content of development is more knowledgeable and service-based. In this way, much of the content no longer needs to be as concentrated as industrial production, and much of the environment and traditional culture is scattered across rural areas and small towns. As a result, many new economic scenarios may emerge in rural areas and the relationship between urban and rural areas will be redefined.

2) Urbanization in digital and green era

This means that in the digital era and the green era, there will be two major trends in urbanization: a tendency of concentration and fragmentation side by side.

One is centralization, that is, the wider population is connected to the rapid transit system and the Internet and access to the various services and knowledge that in the past required physical population concentration in the cities. No matter when and where, all can be connected, with the Internet for a variety of activities. Many public services can be provided centrally on-line.

The second is decentralization, where economic development no longer depends so much on the physical concentration of the population as in the past. Many specific economic activities can be decentralized under the condition of sharing a centralized platform. For example, although intelligent manufacturing is based on decentralized small manufacturing units, it shares a platform of common design, development and promotion.

For the future trend of urbanization, academia seems to have yet to reach a consensus. There are two different kinds of observations about the future

pattern of cities. One is the support for decentralized trends. Evidence from Hendeson et al (Baum-Snow, et al., 2017) shows that with the advent of high-speed railways, cities in China are showing divergent trends. One is to think that internet and convenient transportation will speed up population concentration in big cities, such as Glaeser(2011). These two different observations may be due to the different definition of the urban population's time and space. Therefore, the research on the actual spatial distribution of population and economic activities based on big data can depict the real situation more accurately than the traditional statistics.

In the meantime, the hierarchical structure of cities will also undergo substantial changes accordingly. The urban and the rural will be no longer as distinct as the traditional industrial age, the rural areas can also have the high quality of life as in modern city, and have many economic activities with high productivity.

2.1.3 Future of Green urbanization in China

China's future urban green transformation will evolve in two complementary directions at the same time.

In the first direction, the reshaping of the existing cities is to adapt to the new production and lifestyle in the digital green era. As the spatial pattern of the existing cities has been locked in, physical changes are more difficult. However, the above-mentioned new changes that determine the pattern of cities have also greatly changed the production and way of life of existing urban residents. New things like online shopping, internet-based mobile office, shared transportation, zero-energy buildings and others are profoundly reshaping the city's functions in the future. For example, some traditional department stores, which have been hit hard by online shopping, are transforming into an experience store with various functions.

The second direction is that a large part of the newly added urbanization will adopt a new green concept and mode, and a large number of new towns with characteristics will emerge. Compared with 70% urbanization in developed countries, China's current urbanization rate is relatively low, and there is still much room for growth in the future. However, in the future cities and villages may no longer have the same difference as in industrial age since small-and-medium-sized cities, suburban areas, characteristic towns and villages may also carry high productivity economic activities and high quality of life. Their difference from big cities are only a physical form, rather than the

difference in quality of life. With the emergence of new job opportunities in villages and the substantial improvement in the quality of rural life, a large number of new "urban and rural amphibious populations" will emerge. The traditional statistical methods for urbanization need to be changed accordingly.

2.1.4 Green urbanization challenges facing the transformation

First, the lock-in effect. Many infrastructures were developed in the thinking and technologies in the industrial age. For example, central heating, centralized sewer pipelines, centralized waste treatment, centralized energy supply and more.

Second, the mainstream economic development model is still based on the traditional industrialization logic. For example, many industrial parks and manufacturing facilities are not well planned. Under such conditions, the issue of urbanization can only be relied on for better "urban planning and design" of new areas and for the redesign and restoration of brownfields.

2.2 Redefining the Countryside: Rural Revitalization and Green Leapfrog Development in Poverty Region

In the traditional model of industrialization and urbanization, the rural areas are more defined as "places for providing agricultural products, raw materials and surplus labor for industrialization." Before the massive process of industrialization began, China had been a rural society based on agriculture and handicraft for thousands of years. They formed a unique way of life and production in rural society and formed the foundation of traditional Chinese society and culture. To revitalize the rural areas, the village must be redefined from the concept of "agricultural place"(*Nong Cun* in Chinese) in the traditional industrial era to the concept of modern "village" (*Xiang Cun* in Chinese) so to think outside of the traditional thinking of industrialization and urbanization. This means that in the digital and green development era, the countryside is no longer merely a place "providing agricultural products, raw materials and surplus labor for industrialization", but rather a new geospatial space that can carry a large number of emerging modern economic activities. Under this new thinking, the development prospects of the countryside suddenly become bright. Poor areas with a large number of "green" endowments are expected to accelerate development through green leapfrog.

2.2.1 The Great Development of Rural China and Its Problems

The rural population has achieved a substantial increase in income levels. China is a leader in global poverty reduction. Rural housing, education, life expectancy, and infrastructure have all been significantly improved. At the same time, however, rural areas are also exposed to huge environmental, social and cultural costs and growing urban-rural differences.

● Environmental Costs: Not only the environmental problems caused by the transformation of traditional ecological agriculture in the past into industrial agriculture and chemical agriculture, but also the transformation of rural production and lifestyles by industrialized products resulted in the disintegration of the original social and economic ecosystems and the rural pollution becomes a systemic problem. In this case, individual efforts will not help. For example, straw was replaced by gas stoves, and organic manure was replaced by fertilizers.

● Social Costs: left behind the elderly and children; price of families separation (emotional, educational and social issues).

● Cultural Costs: The original way of production and lifestyle on which the local culture is based has undergone drastic changes and the foundation of culture has declined.

● Differences between urban and rural areas: the difference is not only the result of urban-rural barriers, but also the product of the traditional industrialization model.

As pointed out in chapter one, these problems are largely inevitable consequences of the traditional model of industrialization. Under the traditional industrialization mode, economy, environment, society and culture are largely conflicting relations.

The lagging behind of China's rural areas has its specific institutional reasons. In the era of planned economy, rural areas made great sacrifices because of the price scissors between industrial and agricultural goods was used to accumulate capital for industrialization. After the reform and opening up in 1978, industrialization and urbanization began to accelerate, and a large number of elites in rural areas went to the cities. Due to the institutional barriers between urban and rural areas and the rural land system, urban talents and other production factors can not flow to rural areas. Economic development has then become a "water pump", all kinds of rural talents are drawn to cities in one way.

2.2.2 Redefining the Countryside: 2020-2050

So, how to solve rural problems? As Einstein pointed out, "We can not solve the problems by using the same kind of thinking when we created them". The traditional logic of industrialization is the root cause of rural problems. The solution to these problems is to think outside of the traditional industrial thinking.

The way out for rejuvenating the countryside lies in redefining it from the traditional "rural"(*NongCun*') concept to the modern "countryside"(*XiangCun*) concept. '*Nongcun*', in Chinese means agricultural place, is an industrial concept corresponding to industry, meaning that the rural area is merely a supply base for agricultural products, raw materials and agricultural labor. The concept of modern '*Xiangcun'* is a concept of new geographical space, which means that it not only provides agricultural products, but also carries a variety of emerging activities relying heavily on the country's unique ecological environment and cultural resources. In the era of mobile Internet and digital age, this advantage is even more prominent in rural areas.

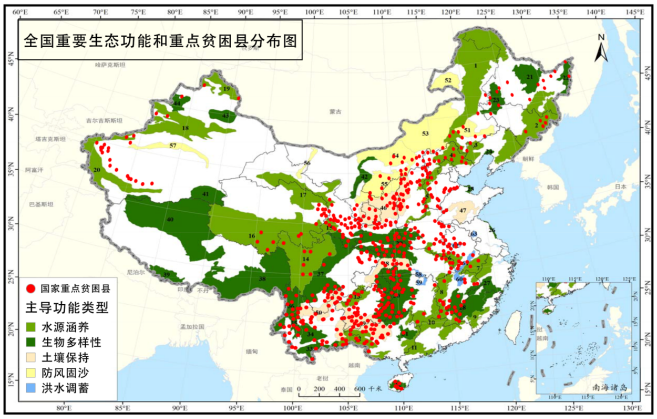
The good ecological environment and cultural endowments owned by rural areas are inherently precious resources, but these resources are hard to use in traditional development concepts and industrialized models. Once mindset or development concept is changed, the value of these resources would become apparent. With new technologies, new business models and mechanisms in the digital age, they could through market be translated into new development content, or new supply, namely, tangible products and services, and become a major new source of growth. There are many innovative cases of "redefining the countryside" in China. For example, Shishou in Hubei province, Daming in Hebei, and so on.

Although the general trend of the transfer of agricultural population to the cities will not be changed, the population in rural areas engaged in non-agricultural economic activities and residing will also increase than in the BAU scenario due to the new opportunity in modern *Xiangcun*. Such population may not necessarily be classified into "either citizen or farmer" category in the traditional urban-rural relation, and may be a new type of "amphibious population" traveling to and from the urban and rural areas. For example, one has a permanent residence in a city can spend more time working or living in the countryside.

2.2.3 Green Leapfrog in Poor Areas in China

The so-called poverty-stricken areas actually have excellent agricultural resources, ecological environment and rich local culture and other resources. In the past agricultural age, many of them were actually relatively "rich places." However, with the advent of the industrial age, this kind of resources has no advantage in industrial production and they become lagging behind in the industrial age. However, the rise of the concept of green development, the advent of the digital age, the popularization of fast transportation networks, and the substantial increase of China's development level and comprehensive strength have brought the areas new historical conditions that the developed regions did not have when they took off. This has brought new historical opportunities for the development of poverty-stricken areas. With these new advantages, they are likely to turn their "green" into real "gold" under the new concept of development and take a new leapfrog development path.

Fig 30 Ecological and environmental advantages in poor areas: Distribution of important ecological functional zones and key poverty-stricken counties in China



Note: The red dots in the figure indicate the location of the national poor counties.
Source: made by the author.

Table 1 overlap between poverty counties and ecological function areas

	number	share
Poor county	573	
same function zone	516	90.05%
different function zone	57	9.95%

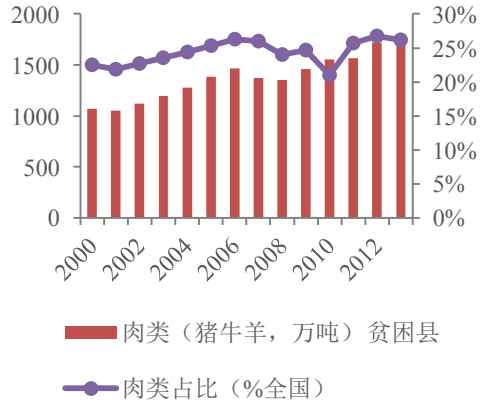
Source: made by the author.

Ecological Advantage: Most of the poor areas in China are classified as "restricted area for development" in the "main function zone" classification in China. Among them, poverty counties and ecological function zones overlap by 90.05%, while the capital towns in poor counties have 79.93% overlap with ecological function zones, while the capital towns are the major industrial development areas in poverty-stricken counties. This means that on the one hand, due to the policy restrictions of the main function zones, these areas can no longer follow the traditional industrialization path on the policy side; on the other hand, poverty-stricken counties have unique advantages of "green" resources.

Advantages of modern green agriculture. As shown in Figure 31 and Figure 32, the output of agricultural products in poor areas in China is considerable. Among them, the meat output accounts for about a quarter of the country's total, while grain output accounts for about one-fifth. If their agriculture could be transitioned to high value-added modern ecological agriculture, their advantages can be fully exploited.

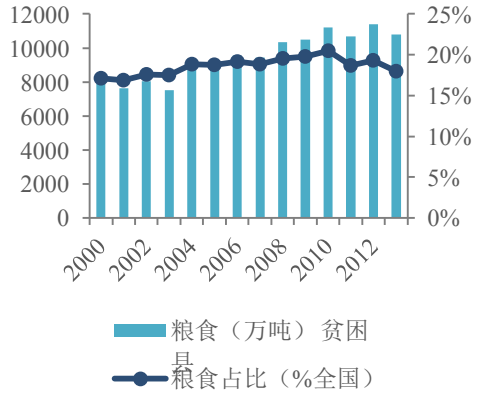
Local cultural advantages. Due to underdevelopment the impoverished areas fortunately have not been heavily hit by the traditional industrial production and lifestyle, but rather have well conserved their rich local culture.

Fig 31 The production and proportion of meat in poverty-stricken counties



Note: legend is Meat production in poverty county, proportion in poverty-stricken counties
Source: China National Bureau of Statistics（2016）

Fig 32 Food Production and Proportion in Poor Counties



Note: legend is Food Production in poverty county, proportion in poverty-stricken counties
Source: China National Bureau of Statistics（2016）

2.2.4 Challenges in Revitalizing the Countryside

First, the rejuvenation of the countryside is a systemic issue. The environmental problems in the rural areas are not only caused by the transformation of ecological agriculture into chemical agriculture, but also by the systemic industrialized transformation of the farmer's production and lifestyles. The rural pollution has become a systemic issue, and any single effort would be little helpful.

Second, if the traditional thinking of the industrialization is unchanged, the rural areas will only be able to duplicate the cities, making it hard to really rejuvenate. The mode of production and lifestyle in rural areas have largely been transformed by the logic of industrialization. The local culture based on past production and lifestyle is losing its roots.

Thirdly, if agriculture as the mother industry for the rejuvenation of the countryside continues to be "modernized" according to the logic of industrial & chemical agriculture, the most unique ecological & cultural value of the countryside will not be reproduced.

Fourth, the rejuvenation of the rural areas requires the introduction of external forces combined with local forces. The poor access of urban talents to rural areas due to some institutional barriers is a prominent issue. At present, the huge needs in the cities to the countryside (including business, pension, housing and other needs) can hardly be met. Once this huge demand could be directed into countryside through innovative institutional arrangements, the development of rural areas will be injected new vitality.

Fifthly, the redefined rural areas have a host of new green development business opportunities, but these opportunities are not only difficult to be fully understood and recognized by those who are accustomed to the business models in industrial age, but also the realization of these opportunities depends on systematic transformation. The individual firms do not have the capacity to make these opportunities a reality through systematic shift. This requires the coordination and promotion of the government.

Summary: Reshape the New Spatial Pattern and Urban-Rural Relations

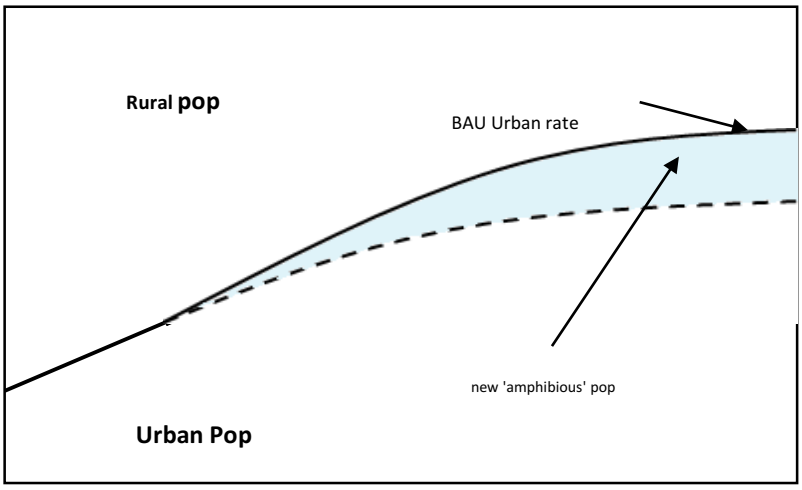
First, the existing urban, rural and urban-rural relations are largely the product of the industrial age and do not meet the needs of the digital age and green development.

Second, the traditional concepts of city, countryside, and the urban-rural relation are being redefined, and the factors that determine the spatial pattern are also undergoing substantive changes in the new context, including the rise of digital age, the era of high-speed rail, online shopping and rapid logistics, profound changes of development concept and development content, etc.

Third, although the trend of massive transfer of agricultural population to cities will not change, with the unique advantages of rural ecological environment and culture, a large number of emerging non-agricultural economic activities and new job opportunities will emerge in rural areas. The functions and patterns of existing urban communities will also be reshaped as production and lifestyle changes.

Fourthly, there will be a large number of 'characteristic towns' in the metropolitan area conveniently interconnected by high-speed rail and rapid transit systems. They enjoy both urban conveniences and rural advantages.

Fig 33 New urban-rural spatial pattern in China 2020-2050



Note: The BAU scenario urbanization rate curve is made according to Figure 30, and the dotted line is conceptual. Due to the redefinition of countryside, some non-agricultural activities that previously did not exist have brought in more jobs and residents than in the BAU scenario. However, many of these non-agricultural population may be the new "amphibious" population travelling between urban and rural areas or live in "characteristic towns" of the metropolitan area. We can not accurately predict the number of such changes.
Source: DRC Green Development Research Team

Section 3 Reshape Green Infrastructure

Infrastructure is a prerequisite for economic development. The content and form of the existing infrastructure is largely a product of the traditional industrial age. With the advent of the digital green era, not only the traditional infrastructure will be changed, but new infrastructure will be required. The former refers to the greening of infrastructure related to water, electricity and roads. The latter refers to the necessary conditions for the new economy, including mobile Internet, digitalization, ecological environment, landscape design and culture. To achieve a green transition in China's economy, it is necessary to reshape the green infrastructure.

3.1 China's tremendous achievements in infrastructure

In the past four decades, the tremendous achievements made by China in its development have largely been attributed to the great development of infrastructure. China has made great strides in energy, roads, transportation and construction.

Energy: From 1978 to 2016, the total primary energy consumption increased from 586 million tons of standard coal to 4.36 billion tons of standard coal (NBS, 2017; Figure 34).

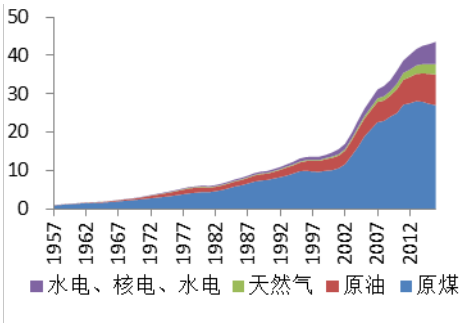
Roads: During the period from 1978 to 2016, the standard highway increased from 510,000 kilometers to 4.23 million kilometers. In 2016, the national freeway exceeds 130,000 kilometers, started from zero in 1988. Over the same period, the mileage of railways operation increased from 53,000 kilometers to 124,000 kilometers. Started from zero, by 2016, the total mileage of high-speed rail operations has reached 22,000 kilometers (NBS, 2017; Figure 35).

Transportation: The factors affecting traffic energy consumption can be grouped into four categories: activity level, transport structure, equipment efficiency, and fuel structure. According to Yi Wenjing (2017), in 2014 China's transport energy consumption was 430 million tce of standard coal (300 million t of standard oil), accounting for 13.7% of the total final energy consumption. Transport energy consumption has been on an upward trend since 1996. In absolute terms, transportation energy consumption has increased from 110

million tons of standard coal (80 million tons of standard oil) in 1996 to 430 million tce of standard coal (300 million ton standard oil), nearly quadrupled, which was significantly faster than the energy consumption of the whole society.

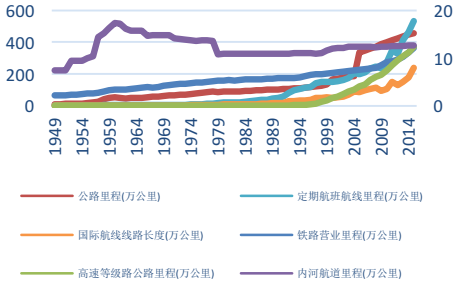
Construction: During 1978-2016, the per capita residential area in the city increased from 6.7 square meters to 36.6 square meters, an increase of 4.5 times (Figure 36).

Fig 34 China's primary energy consumption (100 million)



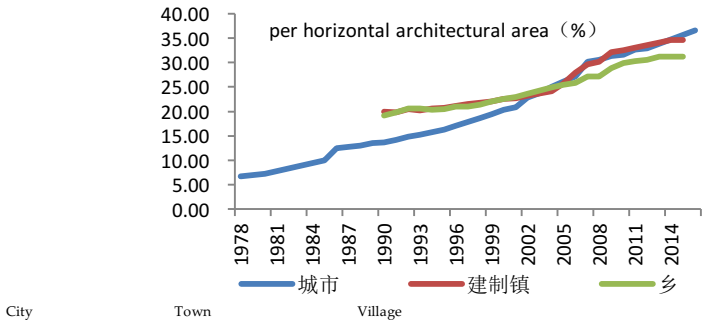
Note: Legend from left to right is Hydropower and nuclear power, natural gas, crude oil, coal
Source：Wind

Fig 35 China Transportation Infrastructure Construction 1949-2016



Note: Legend from left to right is highway mileage, regular flight mileage, international flight mileage, railway operating kilometrage, expressway mileage, Inland waterway mileage
Source：China National Bureau of Statistics http://data.stats.gov.cn

Fig 36 Growth of Average Residential Area in China 1978-2014



Data source: Ministry of Housing and Urban-Rural Development

3.2 The Main Problems

First, such infrastructure and infrastructure are not green enough. For example, buildings are energy-consuming, energy depends on fossil fuels.

Second, the infrastructure mainly focuses on hardware infrastructure required for industrial production, including infrastructure in water, electricity, roads, gas, etc, cannot fully meet the new needs of the digital & green era.

3.3 Reshaping Green Infrastructure 2020-2050

1）Two directions of green transition

First direction: the greening of existing traditional infrastructure

By 2035, the turning point of green technologies such as new energy, transportation and green building will come（LBL, 2017; REN21, 2017; World Bank, 2016; McKinsey, 2009）. According to the Reinventing Fire China Project (ERI, LBNL and RMI, 2016), China's energy-related infrastructure sector has huge potential for greening.

Second direction: the supply of new green infrastructure

Ecological and Environmental cleaning-up: Government investment to improve the ecological environment can create huge ecological services. The return on ecological investment is actually high, but the way of return is different from industrial projects. The government should fully recognize the role of these intangible public goods in enhancing economic development and people's well-being.

Local culture protection and revitalization: investigating, sorting out, improving, promotion, and development.

Digital infrastructure: providing conditions for the digital economy.

2) Potential of Green Infrastructure Transition in China: 2020-2050

The first of these two directions of green transformation of the infrastructure described above directly reduces energy consumption, emissions and pollution through the greening of infrastructure; the second is the indirect reduction through catalyzing new green economy with new

infrastructure. Here we mainly focus on the environmental effects of the first direction.

The Reinventing Fire Project (ERI, LBNL, RMI, 2016) conducted a very detailed bottom-up investigation and tracking of the cost-effective technologies and their applications, and identified the key time nodes for green transition in different infrastructure sectors.

Energy Systems: New energy and clean energy technologies have developed rapidly in recent years. In many parts of the world, the cost of solar and wind energy can already compete with traditional energy or natural gas.

Buildings: It is now cost-effective for all new buildings to meet the 3-star green building requirements in China by 2020 and the standard can be updated every five years thereafter. At the same time to encourage the prefabricated building to reduce the construction waste.

Energy Systems of Building: It is cost-effective that, beginning in 2020, all new building energy systems (and interior appliances) must meet the best international standards. As a leader in appliance manufacturing, China can lead energy consumption / environmental standards for home appliance production, including refrigerators and air conditioners.

All new urban areas must meet the multi-purpose and transit-oriented development (TOD) principle, have high quality public transport, and secure, comfortable walking and cycling lane infrastructure. Urban infrastructure planning should be highly resilient to adapt to the effects of climate change.

All public transport and fleet vehicles (buses, municipal LDVs / trucks, rental and shared transport) are all converted to electric vehicles or hybrids by 2025.

The RF China project also found that to switch to cost-effective clean energy technologies, China needs to invest more than 35 trillion yuan, but it can save 56 trillion yuan in fuel costs and 21 trillion yuan in 2010-2050.

The green transformation in infrastructure brings huge investment demand. According to Paulson Institute's estimate, green building renovation technology has become a cost-effective technology. The green building renovation project will bring about 224.8 billion yuan of market investment demand during the "13th Five-Year Plan" period.

3. 4 Challenges of Green Infrastructure Transition

Without forceful measures to overcome the following difficulties, the above transformation will encounter great resistance. Taking the transport sector as an example, based on a review by Yi (2017), in the BAU predictions of transport energy use in China conducted by the IEA, EIA, BP, APEC, the Lawrence Berkeley National Laboratory (LBNL), Energy Research Institute (ERI) and other leading research agencies, no significant turning point will occur until 2050. Therefore, the green transformation of infrastructure will not happen automatically, unless a forceful policy is adopted.

First, the lock-in effect caused by sunk costs and path dependence in infrastructure make transition costs very high in many sectors. The existing infrastructures were mostly formed in the traditional industrial age. Many of them are not suitable for the needs of green development, but the changes are very difficult.

Second, the current set of institutional arrangements and policy designs on infrastructure have to a certain extent impeded the development of new infrastructure. For example, zero-energy houses, while economically viable, may be hampered by the impact on thermal companies since their business models of centralized heating rely on the existing subsidy system, and sunk costs of investment are all formed in the traditional model.

Third, financing mechanisms for green infrastructure. According to the Paulson Institute's research (Mo, 2017), it is not because there is no market demand for green building and contract energy management, but due to mechanism design issues including green finance mechanisms. If green building insurance and contract energy management financing could be introduced, then a huge market could be activated and a new win-win situation will appear.

Section 4 China's Green Transformation Potential: 2020-2050

4.1 Introduction to Green Transformation Scenarios

What needs to be particularly emphasized is that the scenario analysis in this discussion paper is predominantly conceptual, i.e. not fully quantified. Given the enormous uncertainty and complexity of China's green transition to 2050, we do not pretend to make precise quantitative projections of developments. Thus, the focus of the current discussion paper report is not a quantitative outlook for 2020-2050 but an exploration of the problems associated with the transition and the corresponding institutional and policy recommendations. As for the specific shape and quantity of green economy in the future, this is subject to an evolution that is determined by market forces under the intervention of these systems and policies.

Though there are still many questions about green development (e.g. Unmüßig, et al., 2012), now more and more theoretical and empirical studies show that green transformation can lead to better growth rather than a burden of growth. Several major theoretical lines and empirical studies in this area are emerging (e.g. Acemoglu et al, 2012; Hallegatte, et al, 2012; Jaeger et al, 2011; Zhang and Shi, 2014; New Climate Economy, 2014; World Bank, 2012; UNEP, 2011). If green is deemed as a general term of non-material production factors and services, then the deep economic implications behind can be explained in plain language.

First of all, "green" is "gold" and has great value. The purpose of development is to satisfy all-round needs of people, including material needs, namely, "people's ever-growing needs for a better life", while the various invisible ecological products and services provided by the ecosystem are vital parts of such "needs for a better life", and therefore is valuable. Behind this is the rethinking of the fundamental question of value theory in economics. Of course, based on these "new" resources and needs, a great deal of green new supply can be generated.

Second, how can the intangible "green" be translated into real "gold". In particular, in digital age many new business models have emerged that are different from that of industrial age. Through effective mechanism design, policy design and innovative business models, these invisible green resources can produce new supply. Once the various transitional barriers discussed in

the previous chapters could be addressed, "green" can replace the non-green sources of growth in traditional industrial age.

Third, "Green" has both high productivity and is sustainable. Non-material production factors and services are usually non-rival that can be used simultaneously and repetitively. This nature can become an important source of increasing returns in economic growth. Due to this nonrival nature, the investment in eco-environment can actually generate high returns, but the way of high return is different from that of industrial projects. In many cases, they are reflected in the form of external effects and require new business models. Moreover, the green resources such as culture and big data are sustainable resource----they will become more and more, and will never be exhausted like material resources.

4.2 Scenario setup

We distinguish two main scenarios: Business as usual (BAU) and Green Transition Potential. Additional, specific scenario-based information has been mobilized to explore (i) the worldwide implications of China's green transition, and (ii) more radical climate mitigation in the energy sector. For its quantitative findings, this paper draws on four coordinated sources:

- modelling by the green team at Development Research Centre of the State Council; focusing on economic changes
- scenario analysis by PBL Netherlands Environment Agency, on implications of China's green transition in terms of world regions, including China itself.
- compared with recent results of the Re-inventing Fire project, on changes in China's energy sector
- ad-hoc modelling by DNV-GL of Norway, on the potential of a more radical and early shift from fossil to renewable energy in China's energy sector

For the 2020-2050 Green Transformation Potential, we focus on two dimensions: economic growth and environmental effects. In the economic growth dimension, the DRC has modeled the changes in growth rate, total GDP and economic structure. In the environmental dimension, we rely on the results of pre-existing simulations, highlighting effects on environmental quality, carbon emissions and material resource consumption brought about by green transition.

Underlying the DRC projections of the green transformation potential is the positive vison that economic growth and environmental benefits effects are mutually reinforcing, given the right framework of policy and institutional arrangements. On the one hand, a good ecological environment can spawn a large number of emerging economic activities that are pro-environment and cultural. Thus, the improvement of ecological and environmental quality becomes one of the driving forces for growth. On the other hand, green economic growth also provides momentum for environmental protection and culture protection. In other words, an underlying assumption is that in China, during the coming decades, economic growth and environmental protection can be made mutually reinforcing, as in: "the more protection, the more development ".

The scenarios divide 2020-2050 into two periods: 2020-2035 and 2035-2050. The midway point, 2035, constitutes an important pivot point. In general terms, the first period, up to 2035, is considered the time for China to round off *socialist modernization* while the period up to 2050 would be characterized as the realization of China as a *modern power*.

More specifically in terms of economy and environment, this paper highlights a number of necessary changes to China's systems that should be in place by 2035, being the must-have conditions for its transition to 2050 to succeed and deliver its green potential, effectively and to everyone. Thus, the policy agenda up to 2035 will carry important work that is long-term and, at the same time, urgent. Sections II provide examples.

Against this strategic background, 2035 environmental ambitions would assumedly be prioritized on the principle of "what can be done", that is, to catch up with the existing highest level in all fields in the world in the relevant planning goals set by the Chinese government. This includes China's national interpretation of the 2030 SDGs. Then, by the second half of the scenario period, China's green transition assumes increasing emphasis for environment management on "what must be done", based on a positive vision and considering the relevant global targets for sustainable development.

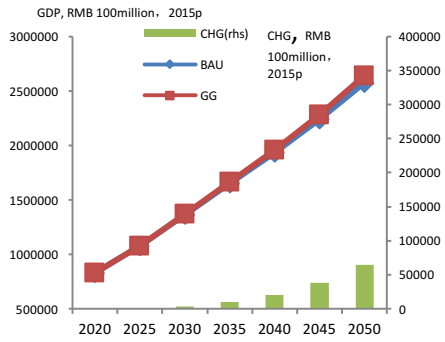
4.3 Green Transition Potential: The Economy

In terms of overall level of China's GDP, and thus in growth rates, the projections by the DRC show little difference between transition and BAU. (See Figure 37 and Figure 38) The intuitive reasoning is that the efficiency

improvement in traditional sectors and new service sector will become important source of growth, and improvement of the quality of the environment will spawn a large number of pro-environmental economic activities, especially in the services sector. In addition, the effect of improved immaterial resources such as culture on economic growth is generally felt most in the setting of service economy. These elements would come on top of the basic shift in economic emphasis in China from classical manufacturing towards services. Therefore, our analysis focuses on changes in structure rather than overall levels of GDP.

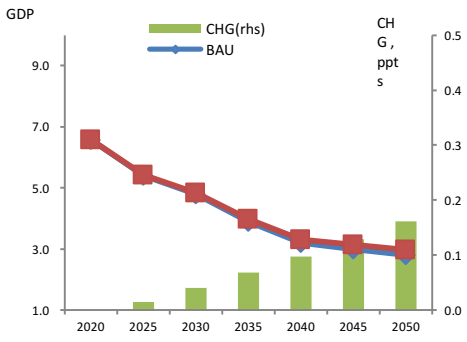
In this vein, the three main production sectors of the Chinese economy develop differently under the conditions of green transition compared to BAU. The service sector will anyhow feature the largest change. (See Figure Y in this paper and Figure 3.2 in PBL, 2017.) By 2035, the difference in GDP under the two different scenarios can be contributed 74% to the service sector. By 2050, the contribution of the service sector disparity rose to 82%. The green transition is more reflected in the emergence of emerging services because, like emerging information services in the digital economy, emerging green services are also an essential part of a green economy.

Fig 37 Impact of China's Green Transformation on GDP 2020-2050: GDP: BAU vs. GG



Source: made by DRC green team.

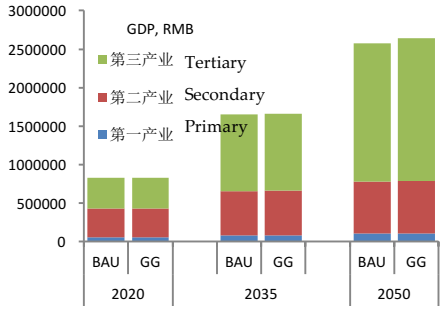
Fig 38 Impact of Green Transformation on Growth in China 2020-2050: GDP growth: BAU vs. GG



Source: made by DRC green team.

Fig 39 The Impact of China's Green Transformation on GDP Content 2020-2050

Change of GDP：Content: BAU vs. GG



Source: made by DRC green team.

4.4 Direct Effects on the Ambient Environment in China

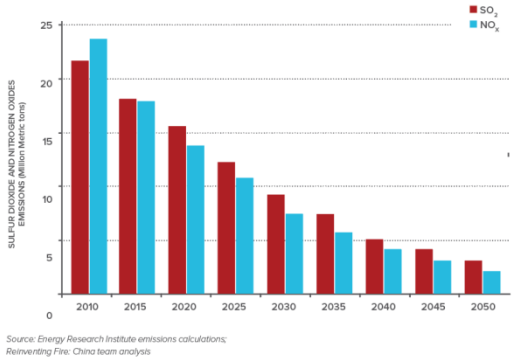
The impacts of China's Green Transition Potential on its ambient environment are illustrated here using projections related to air pollution; quality of inland waters; forest; and carbon dioxide emissions. These projections come from the Reinventing Fire project and from PBL's scenario analysis of worldwide implications (PBL, 2017)

According to Reinventing Fire's simulations, energy-related emissions of major air pollutants, such as sulfur dioxide and nitrogen oxides, can be significantly reduced in the green transition scenario. A fundamental improvement will have been achieved by 2035. Emissions will remain very low and decrease further towards 2050 (Figure 40).

In its projections of air pollutant emissions, PBL notably shows that a strong decrease of emissions of Sulphur dioxide and black carbon happens anyway, under the conditions of BAU. China's green transition can deepen these reductions, compared with BAU, for example with 45 % for Sulphur dioxide.

But the emissions of nitrogen oxides are more difficult to reduce. Nitrogen oxides are an important ingredient of photochemical smog; a large proportion of their emissions originates from diffuse sources, especially motorized transport. PBL finds that, while a sizeable decrease of nitrogen oxides emissions does occur under the conditions of Chinese green transition (39 % better than BAU), a further, large improvement to 1990s levels could be realized in combination with more ambitious changes, aimed at limiting climate change to a global average of 2℃.

Fig 40 Pollutant Reduction Effects of Green Transition in 2010-2050

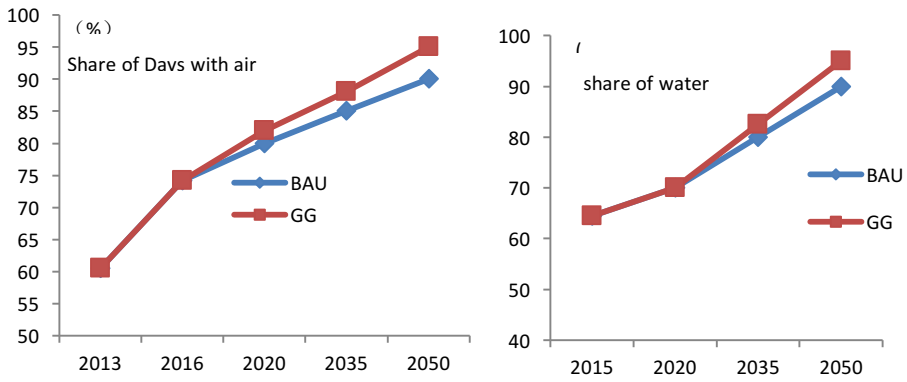


Source: ERI, LBNL, RMI, 2016

According to the scenario analysis of the DRC team, the ecological quality can be greatly improved by 2020-2050. Among other things, by 2035, the proportion of level II days in the BAU scenario is expected to reach 85%, while in the green transition scenario, this indicator may increase by three percentage points. By 2050, the proportion of days in the second-level weather in both scenarios, it is expected to reach 90% and 95% respectively.

In the water environment, the proportion of Grade III water and above in the green transition scenario are 2.5 and 5 percentage points higher than that of the BAU scenario in 2035 and 2050, respectively.

Fig 41 Improvement of Environment quality



Source: made by DRC green team.

4.5 Resource consumption and carbon emissions

Since the consumption of material resources is highly correlated with energy, we regard the consumption of energy carriers as a useful first proxy to examine the resource consumption under conditions of BAU and green transition.

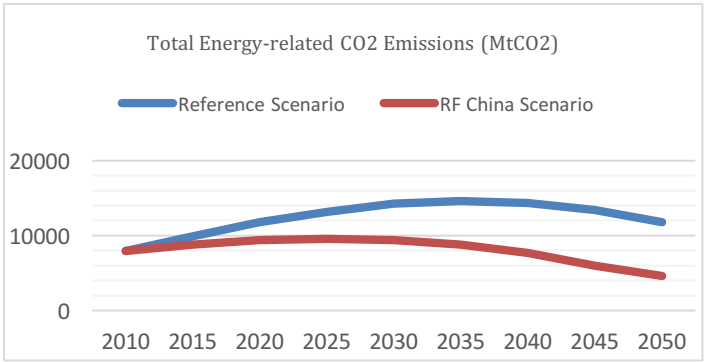
China's Green Transition Potential amounts to a very large improvement in overall energy efficiency, over and above the large improvements already foreseen under BAU conditions. For example, see the development of primary energy demand by China's industry, as shown in figure 42 By 2050, it would have returned to approximately the same level as in 2010 (3.4 Bil tec), while China's economy would meanwhile have grown six-fold.

In a global context, PBL shows China's economy as a whole becoming less energy intensive, approaching the pattern of OECD countries (PBL, 2017; Figure 4.2). Most of this would happen even under BAU conditions. China's green transition would slightly improve upon it.

China's green transition would obviously be reflected in its import of energy carriers. For example, see Figure 4.6 in PBL, 2017. The baseline scenario would see imports of fossil fuels increase strongly. This would happen in a green transition scenario, too, except for coal. Under a scenario aimed at achieving the internationally agreed climate target, imports of natural gas into China would grow and shrink again, reflecting its role as a transient fuel.

Figure 42 shows China's energy-related emissions of carbon dioxide decreasing 42 % between 2010 and 2050, based on projections by the Reinventing Fire project. However, it should be compared with the PBL projections in a global context, briefly discussed in the next section. These show China's total emissions of carbon dioxide and they compare with the trajectory needed to achieve the agreed climate change mitigation target of limiting average global warming to 2℃.

Fig 42 CO_2 emission reduction of Green Transition（MtCO2）2010-2050



Source: ERI, LBNL, RMI, 2016

4.6 Global environmental implications of China's green transition potential and vice versa

China's green transition potential is linked to the worldwide environment in important ways. The task force explored a number of these, as follows. Details can be found in PBL, 2017 unless stated otherwise.

A comparison was carried out of China's Green Transition Potential as quantified by the DRC with two sets of recent authoritative scenarios by international teams;

A preliminary model-based scenario-analysis was carried out of China's Green Transition Potential, incorporated in a worldwide *middle of the road* scenario;

Because the worldwide scenario-analysis showed that China's Green Transition Potential as quantified by the DRC would be insufficient to achieve the agreed climate change mitigation target of limiting average global warming to 2℃, two additional analyses were carried out:

modelling, by DNV-GL of Norway, exploring the effect of stopping investment in new fossil fuel capacity in China as of 2020 on China's overall economy and its emissions (DNV-GL; special model runs based on DNV-GL, 2017)

model-based analysis, of a scenario of worldwide cost-effective action aimed at achieving the two-degree climate mitigation target

As a proxy for use of natural resources, a synthesis of China's role in the global land and food system, based on scenario analysis for the recent Global Land Outlook

Identification of examples of policy conditions that, from a global perspective, stand out as prerequisite for China's green transition potential to be achieved successfully and in a green way.

The main findings of each of these are as follows.

The overall trends in the green transition pathways as quantified by the DRC green team lie within the bandwidth of international scenarios such as the shared socio-economic pathways. China's green transition pathway appears much greener than any of the international scenarios with which it was

compared because its GDP growth comes from the service sector. Whether this greenness will in fact materialize is however dependent on policy.

China's share in global energy use and emissions is larger than that of any other country and China is expected to keep this role in the future. The important role of China means that development impacts reach far beyond its borders. The implementation of China's Green Transition Pathway reduces China's share in global carbon dioxide emissions and energy use, and leads to less emissions than currently included in most international baseline scenarios. However, international current and planned global policies in combination with China's Green Transition Pathway are not enough to achieve a two-degree target. Additional mitigation efforts are required to further reduce greenhouse gas emissions.

A scenario of worldwide cost-effective climate action aimed at limiting global average warming to 2℃ above pre-industrial levels would indeed set China on such an emissions trajectory, or nearly so. Most of the additional greenhouse gas emission reductions in China would be achieved by further reducing non-CCS fossil fuel use and replacing it with low-carbon alternatives. Global climate change mitigation in the Two-degree Climate Policy projections do not consider the issue of equity, as equal carbon taxes are applied for all regions to achieve the climate target. Depending on the burden-sharing rules, the required Chinese efforts could become smaller or larger, and China's Green Transition Pathway emissions trajectory could be closer to, or further away from, a two-degree Celsius global warming trajectory.

The DNV-GL modelling underlines this. It advocates an early stop, by 2020, to investing in new fossil fuel applications in China for energy purposes. Specifically, it states that an early shift in four areas would put China on a manageable track to achieving climate targets. These four areas are: electricity production, land transport, heating and cooling of buildings, and industrial heating.

Total land demand for agriculture in China is projected to remain stable under the conditions of the global baseline scenario. However, other scenarios would bring land-use changes that largely differ from the baseline development, compared to other world regions. China has little margin in terms of available suitable land, which means that elements of China's Green Transition that influence land demand remain significant. These include agricultural productivity, the proportion of meat in the human diet, bioenergy production and, in specific areas, urbanization.

In terms of land resources, the worldwide context of China's Green Transition looks problematic. Pressures on land resources – soil, water, biodiversity – worldwide will allegedly become larger than at any other time in human history (United Nations Convention to Combat Desertification, 2017). Keeping China's agricultural demand and production stable during the coming decades, while carefully retreating from overly high-input practices, would arguably be China's largest contribution to managing global land resources and the global food system. Specific risks emerge, in particular a very difficult combination of challenges in neighboring South Asia (Van der Esch et al., 2017). Opportunities emerge as well, such as China's leverage in Africa and its potentially exportable experiences in large-scale reforestation.

Some key conditions are apparent for China's green transition to succeed, judging by the necessary scale and speed of the changes foreseen during China's Green Transition in comparison with internationally coordinated scenarios. The following are examples.

Successful policies to steer the supply side of China's production away from its previous path and towards a development that is more like that of South Korea and Japan.

Successful and innovative policies to steer the development of the increasingly important service sector in China, including its new business models, towards a development that is truly green in terms of energy use, waste and transport.

Successful and timely policies guiding how urban development and mobility in the next decades will be organized, in particular in spatial terms.

Fully instrumenting policies aimed at capping and eventually phasing out fossil fuel use well before 2050.

A firm strategy and budget to avoid the interim tool of 'clean coal' locking China into a path of continued coal use at a time when this will be incompatible with agreed international goals. Any application of coal and derived fuels should be accompanied by carbon capture and storage (CCS).

Over and above such technical conditions, social policies are obviously crucial for the transition to succeed. See, for example, the *Study on China's Environmental Protection and Social Development. Executive Report of CCICED Task Force, November 2013* (CCICED, 2013). Such policies will be needed to ease the pain of transition for China's manufacturing industry, as will targeted policies for education.

From the scenario analysis, it is obvious that global and regional collaboration will remain as important as ever, especially with China in a new, more active role. For example, as an element of green transition, China's economy will abandon its role as the world's cheap mass production house. All other things being equal, other Asian economies will take over that role. Regional collaboration can help prevent, or mitigate, a potential continuation of the associated burden to the global environment.

Chapter Three Policy Framework and Roadmap

Section 1 Background of Green Transition Policy Framework

1.1 Approach of Green Transition Policy Advices

Based on the analysis of the previous chapters, this report follows an approach of "analyzing green transition potential (i.e. policy goals) → identifying challenges for achieving the potential (i.e. constraints) → classifying the various challenges (i.e. generalize a policy framework) → problem-oriented policy recommendations" to proposes the policy suggestions.

Green transformation is the most profound and comprehensive paradigm shift on development after the industrial revolution. It is by no means just an environmental and energy issue. The whole set of concepts, modes, systems and policy systems on development formed after the industrial revolution were largely the products of the industrial age with some inherent conflicts with environmental protection.

To solve the problem of ecological environment, we must fundamentally reflect on the development model established after the industrial revolution, make systematic changes on the basis of ecological civilization, fundamentally rebuild the traditional economic system and establish a new green development paradigm for the digital age in the future.

Green development represents great opportunities. The shift in the content of development to meet people's "ever growing needs for a better life" means a host of new opportunities for economic growth that may accelerate instead of hinder economic growth. However, there will be big changes in the content of growth. These needs, to be satisfied by the new supply, can become a new important source of economic growth, and also is essential part of green development.

China's green transformation will take place in two complementary directions: First, the greening of the mode of production. It means that the production is carried out in a greener way. The applications of a large number of mature green technologies that are currently cost-effective could generate

significant investment needs. Second, the greening of lifestyles, that is, the production and consumption of greener content. These means to a large extent the formation of a new green supply and demand based on good ecological environment assets, so to translate "Green" into "Gold".

If such opportunities can be translated into reality, a green transformation will not only improve the quality of development in China, but also accelerate instead of slowing China's development. According to our scenario analysis, by 2020-2050, by 2035, the total GDP under the green transition scenario will be slightly higher than the BAU scenario, with no significant difference. But by 2050, total GDP under the green transition scenario will be apparently higher than in the BAU scenario. Green transition more reflected in the emergence of emerging services. At the same time, the ecological environment is greatly improved.

However, to make this scenario of "more protection, more development" a reality is no easy task. We must overcome various obstacles and establish specific mechanisms and a path for transforming "green" into "gold". For this reason, the policies need to address the various obstacles to the transition.

1.2 Six Major Problems to be Solved through Policy Design

In the preceding analysis, we identified the challenges China faces in realizing the green transformation in the fields of industry, agriculture, services, urbanization, rural areas and infrastructure. These obstacles or challenges can be classified into six major types.

Type one: perception problems. Although ecological civilization and green development have become national development strategies, most of the inherent logics behind them and the essential differences between green development and traditional development models are largely unknown or green development is considered as a "luxury." In many places, ecological civilization and green development remain stuck in the slogan or "old wine in new bottle." They are still pursuing the economy in accordance with the traditional thinking of "big projects" in the past. For enterprises, most of them are accustomed to the business thinking and business models in the industrial age, and do not understand the business model in the digital green era.

Type two: fair competition problems. What Green transition needs most are not subsidies and support, but the real fair competition. The current non-green economy is costlier, reflected in external costs, hidden costs, long-term

cost, and high opportunity costs (i.e., a large amount of environmentally friendly economic activities cannot be carried out with pollution). If these costs are taken into account, the existing non-green economy cannot compete with green economy. However, on the one hand, the traditional non-green economy does not need to bear the external costs; on the other hand, the good environmental effect of the green economy cannot be compensated. This generates an unfairly competition.

Type three: system and mechanism design problems. Many of the existing systems were established under the traditional development model and serve this model, and cannot meet the inherent requirements and needs of green development. Such as local officials' performance evaluation, tax system, financial system, land management system. In many cases, green technologies and new business models could have achieved win-win for all stakeholders. However, this win-win situation is often confined to some specific mechanism designs that are hard to come by. For example, contract energy management can benefit both supply and demand, but lacks of financial support. The same is true for green buildings.

Type four: the role of government. To some extent, green development is a self-fulfilling. On some issues that are in line with the direction of green development in the future, the government can introduce some major measures that can effectively guide social expectations, guide technological innovation, investment and market demand, so that the goal of green development can be self-enforcing.

Type Five: social equity and cohesion. Although green development is good for the economy as a whole, some regions, industries and people will be adversely affected, thus requiring help. Addressing the risks of resistance to the transformation is one aspect. At this point, the government needs to support those affected through appropriate policies, both at the level of individuals and households, for example through support for re-education and training, and at the level of agglomerations and regions, for example through fiscal transfers supporting a period of redefinition and reconstruction.

Type Six: global coordination problems. Green transformation requires global coordination. On the one hand, if a country takes the lead in transition move but other countries do not follow up, it may shortly be able to infiltrate its investment and thus affect its determination to act. On the other hand, when the global have coordinated action together, the green market will expand and investment opportunities will emerge, so the expectation of green transformation will be "self-fulfilling."

Section 2 Overall Goals and Roadmap

Overall strategic goal: Based on the concept of ecological civilization and new development concept, speeding up China's green transformation in an all-round way. Through systemic transformation of development concept, development content, development model, mechanism and policy system, speeding up the process of establishing a mutually-reinforcing "five in one" relation between economy, environment, society, culture and polity towards a new development paradigm.

Roadmap: In the previous scenario, we explore the potentials for China's green transition during 2020-2050 from two major economic and environmental dimensions. Bounded by 2035, the transition targets can be set as catch-up and transformation of key systems by 2035, and partly overtake period by 2050. The catching up by 2035 aims to not only realize fundamental improvement of the environment, but develop new green development model through comprehensively deepening reform, in an effort to transcend the traditional industrial model. The success of transition by 2035 will provide a foundation for realizing the 2050 target.

China has unique advantages in promoting green transformation in an all-round way. Mainly include: First, the forward-looking, long-term and stable policy. The green development represents the correct direction for development in the future and has become China's long-term national development strategy. China will not change its development strategy because of the change of governmental terms. Second, government coordination. Green transformation relies on new green infrastructure, public goods and empowerment, and the transformation needs to overcome strong vested interests. In this case, a strong government capacity is crucial. During 2020-2050, China will build a modern governance system through rule of law, and realize the goal of "let market play decisive role, government play better role".

Phase One 2020-2035: Period of catch-up and transformation of key systems

Period Objectives: (i) To catch up with the economic and environmental goals of developed countries. In particular, the ecological environment has been fundamentally improved and has been fully benchmarked with the

highest global environment standards. (ii) To put in place essential system changes that either take long to realize, have a long-lived impact once in place, or both of these.

- Leading the world in terms of development concept.
- Fundamental improvement in ecological and environmental indicators.
- Basically, establish green development system and policy framework.
- Achieve the major green economy targets in the National plans 2035 ahead of time.
- Breakthroughs made in key areas of green transformation.
- Emerging a number of best practices in global green development.
- In both directions of green transformation, focus on the first transition direction and promote the second direction transformation.

Phase two 2035-2050: Partly overtake and lead period

Period Objective: achieve a complete transformation based on new concept, models, systems and policies. The new development paradigm based on ecological civilization has been established in an all-round way, with fundamental changes in development concept, development content, development mode, system and policy system, and lifestyle.

- Productivity has risen dramatically, but the content of development no longer depends on traditional material resources. In 2050, the economy is highly developed. The economy has entered a stable state at a high level with "prosperity without growth".
- Welfare improved dramatically. In the past, the situation of "high growth, low welfare" has been completely changed. People's happiness level rises with growth and has been at a high level.
- Environmentally sustainability. Due to fundamental changes in the concept, model and content of development, the relations between economic development and environmental issues have largely changed from mutually conflicting past to mutually reinforcing relations. "more protection, more development." Growth does not need to sacrifice the environment as the premise, and a good ecological environment has become an important prerequisite for growth and sources.
- Based on its strong hard power and soft power, China will make a significant contribution to the world.

Section 3 Policy Recommendations: Six Breakthroughs

Since green transformation is a profound systematic transformation from the development concept, content, mode, institutional mechanism and policy, it cannot be achieved through single policy or small-scale efforts. It requires systematic breakthroughs through "comprehensively deepening the reform". The report proposes six major breakthroughs in order to achieve a fundamental improvement of the environment by 2035, and the 2050 green transition scenario. These "breakthroughs" policy proposals do not imply radical policies, rather are all "no-regret" policies, or have been successfully implemented in the world. What we proposed here is more to integrate them in a concerted policy framework, so to achieve the effect of synergies.

Pillar 1: Breakthrough in understanding of the green development

Policy Objectives: The most important issue in China's green transformation is how to solve the issue of how to ensure green development will be no longer remained in the slogan. Under the new green development narrative, new thinking, social norms, and new green lifestyles are formed. Let all levels of government and people truly understand the inherent differences between ecological civilization-based green development and the traditional development model, and make green development operational. Only by making breakthroughs in the understanding of the relationship between environmental protection and economic development, the rigorous environmental protection actions can be taken.

Following the approach of "*establish new green development logic → green education → green demonstration & pilot*", specific policy recommendations including the following elements——

First, establishing a new green development logic. In the relationship between environmental protection and economic development, breakthroughs must be achieved. Let people know the various hazards caused by environmental problems and major opportunities for green development. Clarifying the misunderstanding of "environmental protection is not conducive to economic development". The new green logic will not only reduce the

resistance to action, but will also create a new green consumer psychology and promote green industries.

The second is to carry out green education at multi-level. Solve the cognitive bias toward green development. Addressing the typical concerns on green development from the government leaders and people at all levels, through training and green curriculum so that young people can embrace the concept of green development.

Thirdly, through green development demonstration and pilot projects, the abstract concept of green development will be exemplified so as to make it easier for people to understand and accept.

Pillar 2: Breakthroughs in Key Environmental Issues and Level play field for Green Industries

Policy Objectives: by 2035, prominent environmental problems have been solved and the environment has been fundamentally improved. Creating a level playing field for green industries and provide appropriate incentives: what the green industries need most are not subsidies or favorable policy, but level playing field. Enhancing the "war on pollution" and trying to internalize the external costs of non-green products are the most direct and effective means of promoting green innovation and green economy.

- Introducing stricter standards for the current prominent environmental problems, such as air pollution, food contamination, soil pollution, water pollution and ecological restoration.

- Strict environmental regulations and enforcement. In particular, the use of mobile Internet technologies, drone, and decentralized monitoring mechanisms can significantly reduce the cost of enforcing environmental laws and enhance the enforceability of laws.

- Reassessing various types of subsidies or supportive policies including fossil fuels, chemical agriculture, traditional chemicals, etc., and adjusting them to meet green standards to reduce environmental and social impacts.

- Changing end management to source management. Rewarding the environmental benefits generated by green economic activities is equivalent to using the current state's huge expenditure of pollution control for green industry incentives. Redefining the nature of subsidies for green industries and

return them to attributes of "compensating them for environmental services" instead of being recognized as additional subsidies.

Pillar 3: Breakthroughs in the institution and mechanisms for pro-green development and a full-scale pilot in some areas.

Policy Objectives: To systematically change the current system and policies that do not meet the requirements of green development. From a methodological point of view, many policies can take the lead in carrying out a full-scale pilot in a small area.

- Establishing a new measure of new performance measures (i.e., people's well-being) that is based on "ever growing needs for better life" to overcome the shortcomings of a single measure of GDP. Ecological assets should become a vital indicator development performance measure.

- In cadre performance evaluation, "people's satisfaction" should be taken as an important indicator so as to change the cadre's behavior pattern. Continuing to reduce the GDP weight and give greater attention to environmental and social assessment measures. In particular, after the realization of the goal of an overall well-to-do society in 2020, we should drastically dilute the GDP weight and thoroughly implement the assessment policy of government officials at all levels guided by well-being.

- On the basis of upholding the existing land ownership stipulated by the existing Constitution, activating the farmer's returns from land through the separation of the three rights of "ownership right, contractual right and use right" of land, through a variety of innovations including sharing economy.

Establishing a pro-green local tax system. A substantial increase in the tax on "high energy, high pollution, and resource intensive" products; increase coverage of consumption tax; establishment of consumption-based tax, green transfer payments. Special transfer payments will be made to areas where taxes are highly dependent on high-polluting enterprises (especially the county level).

- Green finance innovation. In addition to introducing green standards into existing financial instruments, it is even more important for green finance to "create new green economy from nothing", and to promote structural changes in the economy. For example, financial risks and financial constraints

need to be addressed in energy contract management, green building and a host of potential emerging green opportunities through innovative mechanism design. Through the green transformation insurance, green development fund, PPP, Internet-based Crowdfunding, and other inclusive finance, encourage green venture capital.

Pillar 4: Breakthrough in "New Green Promotion Action" to Build a Digital Green Economy for the Future

Policy Objectives: boost the confidence in green development and provide a powerful impetus for accelerating the development of a green economy through the introduction of some major landmark policies.

● Designing and implementing a new green infrastructure investment plan. The public investment in new green infrastructure and public goods such as next-generation digital infrastructure, ecological environment and culture will not only directly stimulate economic growth, but also create conditions for new green supply. On the sources of funds, considering allocating state-owned assets in the investment to make state-owned assets better serve the national strategy of green transformation and the interests of all people.

● Promoting economic transformation towards service economy by increasing professional flexibility and expanding vacation time to stimulate new service needs and new supply, such as green leisure and tourism, culture and experience. For example, studying the feasibility of reducing the working hours per week, extending statutory paid holidays by national laws gradually, and implementing various leave systems such as unpaid leave, leave without pay, time-shared leave, flexible leave and flexible work hours.

● Setting a timetable to assess the development goals of existing new energy, electric vehicles, thermal power plants, green buildings and other areas, stopping the construction of new thermal power generation and exploring a bolder approach like that of some countries in Northern Europe. From a certain point of time, limiting fuel vehicles to speed up green transition. One over-arching principle is stopping all high-carbon infrastructure investment to ensure both the peaking of GHG emissions by 2030, and rapid decline afterwards.

● Regarding new urban-rural relations, carry out the new policy of promoting networks of well-connected small and medium size towns, each

with a clear identity. While acknowledging the importance of digital connections for everyone, promote and bring to scale transit-oriented development for any new agglomeration in China. This is to ensure excellent connectivity across the urban network, digitally as well as physically. Set up and use a fast and open exchange of experiences in the renewal of urban-rural relations in China and abroad, especially between now and 2035.

● Breakthrough in promoting new business model based on "Internet +". For example, sharing economy (transportation, accommodation, catering, inclusive finance, etc.).

Pillar 5: Breakthrough in building a more inclusive society and a more resilient economy

Policy objectives: assisting certain groups, sectors and regions affected by the green transformation and establish a corresponding integrated risk prevention and control system. Green transformation should not be seen as threatening or dangerous.

● Improving unified national unemployment security system.

Providing special assistance and capacity-building training for workers affected by Cutting excessive industrial capacity and shutting down zombie businesses.

● Special policy for poor region to achieve green leapfrog. 90% of the existing ecological function areas are located in the poverty-stricken counties in the country. According to the requirements of green development, the existing policies on the development of ecological function areas should be adjusted in a targeted manner to speed up the establishment of "Green" in poverty-stricken areas into "gold" through specific institutional mechanisms and policies.

● Establishing appropriate comprehensive risk prevention mechanisms to enhance economic resilience.

Pillar 6: Breakthrough in Global Governance that Enables the Building of Green Transformation

Policy objectives: Promoting the establishment of a new global narrative on green development with the concept of ecological civilization. At the international level, establishing appropriate institutional conditions and incentives for promoting green development in all countries. On climate change, promoting strategic transition from "burden sharing" to "opportunity sharing" in all countries, and from "zero sum game" to "mutual benefit and win-win."

● Introducing green standards into existing international rules on investment, trade and finance, as well as other international mechanisms such as the AIIB and the G20.

● Promoting the establishment of a global club for green development, providing incentives for countries to reduce emissions and encouraging green growth through international cooperation, and establishing equitable and effective international climate governance mechanisms.

●Establishing a global knowledge hub on green development. Under the framework of South-South cooperation, the Belt and Road initiative, the BRICS program and other frameworks, helping other developing countries to accelerate their development through green transformation. Implementing more stringent green standards in the "Belt and Road" initiative, South-South cooperation and China's strategy of outward investment.

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Annex 1. Global Implications of China ' s Transition (PBL)

Main findings of the model-based scenario analysis of the worldwide implications of China's Green Transition (PBL, 2017)

Early comments on the workplan of the Task Force Team recommended that ample attention should be given to the worldwide context of China's green transition. In order to kick-start work along this line, PBL conducted a preliminary study. It was carried out in collaboration with Utrecht University and supported by the Ministry of Infrastructure and Environment (now Infrastructure and Water Management) of The Netherlands.

From the range of economy-environment issues to be addressed by the task force, the PBL kick-start study focuses on changes in China's energy system and its significance to climate mitigation and air pollution. In order to include at least one other natural resource, comparable assessment results on worldwide land use change have been included, taking advantage of recent work in support of the first global land outlook.

The PBL study has been coordinated with the ongoing work of the task force through

the task force interim report of November 2016, as a guide to scope and lines of inquiry

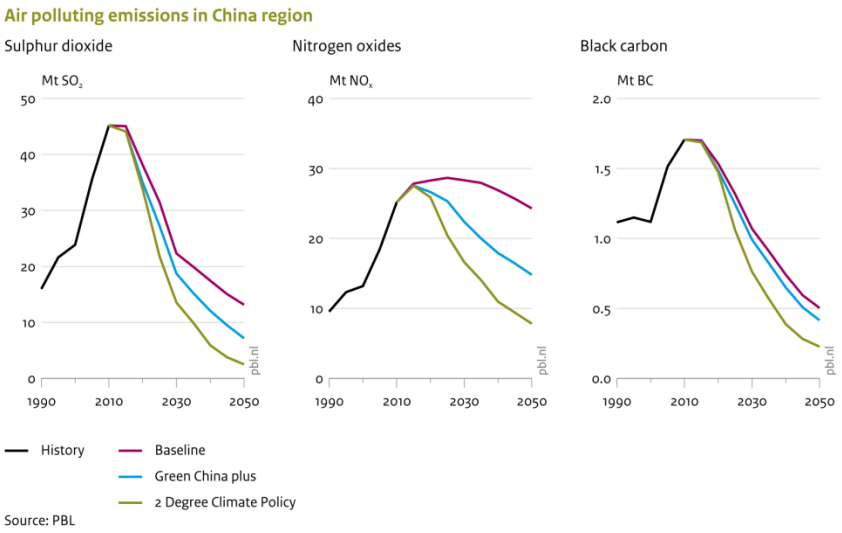
five questions on worldwide context collected from the task force (reproduced in box 1 of the PBL report)

periodic video meetings and data exchange, during the first half of 2017, between the modelers at the DRC and PBL and Utrecht University, in order to ensure consistency and a mutual comprehension of the cause of any differences.

The main findings of the PBL study are as follows:

China's Green Transition Pathway reduces the increase of emissions of important air pollutants towards 2030 and decreases them further towards 2050. Further reductions are achieved when introducing additional climate policy to reach a 2 ^{0}C climate target. These ancillary benefits of additional climate policy would improve the emission reductions to 81% (Sulphur dioxide), 68% (nitrogen oxides) and 55% (black carbon), compared to baseline projections by 2050.

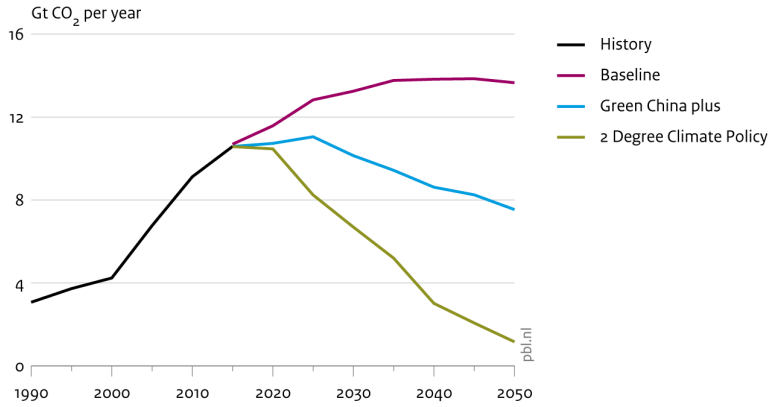
--- A Green Transition would --



A Green Transition would help to achieve environmental goals, in China and globally. However, in order to reach a 2 ^{0}C climate target, China's Green Transition Pathway in combination with worldwide current and planned policies would be insufficient. The temperature levels in the Baseline and *Green China plus* scenario keep increasing, also after 2050. Therefore, additional mitigation efforts will be required to further reduce greenhouse gas emissions in order to reach a 2^{o}C warming target. Roughly speaking, relative to China's green transition pathway in combination with current and planned global policies, a doubling of carbon dioxide mitigation is required until 2050 in order to achieve a 2^{o}C warming target.

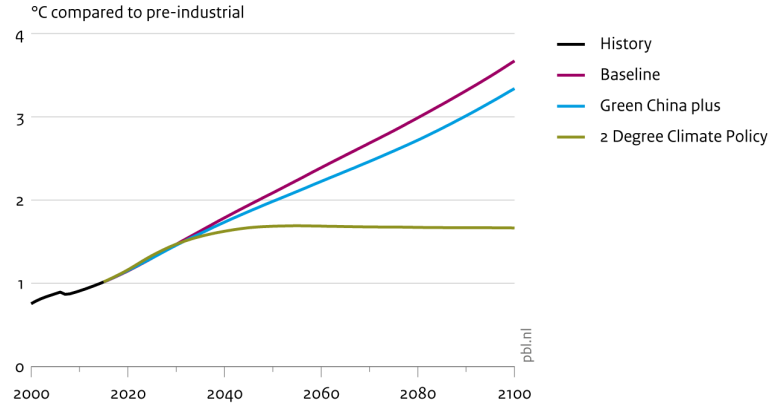
In contrast, the Two Degree Climate Policy would result in the global mean temperature veering towards an increase of 2^{o}C, or less, relative to pre-industrial levels. The emissions trajectory of carbon dioxide in this scenario matches a 66% probability of achieving the 2^{o}C goal by 2100.

Carbon dioxide emissions in China region



Source: PBL

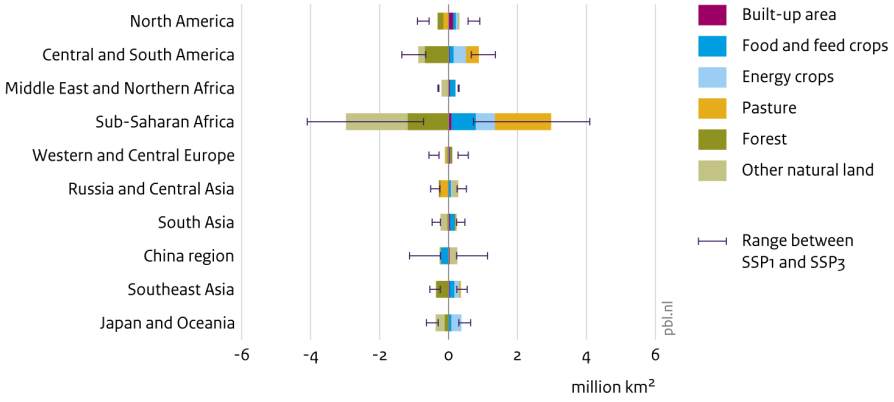
Global mean temperature change



Source: PBL

On issues of worldwide land availability and land degradation, China's Green Transition to 2050 would take place in a world of large, increasing challenges. Relative to the world around it, China's projected overall land use changes to 2050 are modest. However, elements of China's Green Transition that influence land demand are significant because in China, not much more suitable land is available. Such elements of the green transition include agricultural productivity; the proportion of meat in the human diet; bioenergy production; and, locally, urbanization.

Land-use change per region, under SSP2, 2010 – 2050



Source: PBL

In addition, in view of questions posed by the CCICED Task Force on China's Green Transition Outlook to 2050, the PBL report offers the following reflections.

In terms of constraints and synergies of China's Green Transition to 2050, four issues are obvious from a global vantage point.

The current dynamic period in China's development provides a finite opportunity for transition. Importantly, the sheer time required to change important systems, at scale, is significant and these systems tend to serve for many decades, even in fast-changing China. For example, the power distribution grid; urban layout; education systems.

A remarkable risk in the region appears when the scenario outcomes of the Global Land Outlook are viewed together. While China is assessed as a world region with relatively small land-related challenges up to 2050, neighboring South Asia stands out globally as facing a difficult combination of challenges.

Global and regional collaboration remain as important as ever, especially with China in a new, more active role. For example, as an element of green transition, China's economy will abandon its role as the world's cheap mass production house. All other things being equal, other Asian economies will take over that role. Regional collaboration has a function in helping to prevent, or mitigate, a potential continuation of the associated burden to the global environment. Or, considering climate change, it is obvious that China's green transition pathway in combination with globally envisaged policies are insufficient to keep global climate change well below 2 ^{0}C.

Opportunities for China's Green Transition to contribute in a significant way to worldwide management of land resources appear in the findings of the scenario exercise. China's large investments in Sub-Saharan Africa represent leverage in making African agriculture and agricultural land management cope with its challenges –assuming China and Chinese investors will, over the next decades, indeed have good land management practices to export.

At various points in the analysis, key conditions become apparent for China's green transition to succeed. They can be summarized as follows.

Successful policies to steer the supply side of China's production away from its previous path and towards a development that is more like that of South Korea and Japan.

Successful and innovative policies to steer the development of the increasingly important service sector in China, including its new business models, towards a development that is truly green in terms of energy use, waste and transport.

Successful and timely policies guiding how urban development and mobility in the next decades will be organized, in particular in spatial terms.

Fully instrumenting policies aimed at capping and eventually phasing out fossil fuel use well before 2050.

A firm strategy and budget to avoid that the interim tool of 'clean coal' locks China into a path of continued coal use in times when this will be incompatible with agreed international goals. Any application of coal and derived fuels should be accompanied with CCS.

Over and above such technical conditions, social policies are obviously crucial for the transition to succeed. Such policies would be needed to ease the pains of transition for China's current home areas of manufacturing; as well as targeted policies for education. This is outside the scope of the current report.

The report makes suggestions for a fuller version of the current scenario analysis:

Address, in particular, the implications of the transition and its envisaged new business models in the service sector, in terms of fresh water availability and use; air pollution exposure; landscape; agricultural nutrients and pesticides; waste. Of course this would be in addition to energy/climate issues and land use changes.

Be region-specific, possibly with a view to the regional pilot projects proposed in the task force report. Conditions for China's green transition as identified now can then be interpreted in more concrete terms.

Involve Chinese expertise and/or review by Chinese knowledge organizations, in addition to any work by international organizations.

Details of the PBL model-based analysis

PBL looked into possible development trajectories for the economy and energy system in China in a worldwide context. It also considered results of comparable work on land resources. The analysis leads to five conclusions.

China's Green Transition Pathway as elaborated by DRC shows important similarities with the scenarios used in international studies. However, the rapid decrease in coal use that is projected in CGTP is not matched by the international studies. It can only be achieved with ambitious, deliberate policies. In general, the study found a good similarity between the general trends in the Green Transition Pathway and those in the IMAGE-SSP scenarios. Still, in some areas there are differences, as for instance the size of the service sector. Furthermore, China's Green Transition Pathway is characterized by a less dominant role of coal than in any of the SSPs as well as a larger share of solar and wind. The international comparison emphasizes that for this, very strong environmental policies will be needed.

China's Green Transition Pathway reduces energy consumption, greenhouse gas emissions and the emissions of important air pollutants. China's share in global energy use and emissions is larger than any other country and China is expected to keep this role in the future. In terms of per capita resource use, however, the consumption in China is often comparable to current high-income countries. The important role of China means that development impacts reach far beyond the Chinese borders. Implementation of China's Green Transition Pathway reduces China's share in global CO_2 emissions and energy use. The Green Transition Pathway leads to lower emissions than currently included in most international baseline scenarios. Therefore, clearly, China's Green Transition Pathway will require additional policy efforts. As the comparison with Baseline projections shows, energy demand sector efficiency improvements are required. In addition, the use of coal should be massively reduced and efforts are required to increase the share of renewables like wind and solar in the overall energy supply.

International current and planned global policies and China's Green Transition Pathway are not enough to reach a 2 degree target. Additional

mitigation efforts are required to further reduce greenhouse gas emissions. Most of the additional greenhouse gas emissions reductions are achieved by further reducing the use of non-CCS fossil fuel use and replacing it with low-carbon alternatives. Global climate change mitigation in the 2 Degree Climate Policy projections do not consider the issue of equity, as equal carbon taxes are applied for all regions to reach the climate target. Depending on the burden sharing rules, the required Chinese efforts could become smaller or larger, and China's Green Transition Pathway emissions trajectory could be closer to, or further away, from a 2 degree Celsius global warming trajectory.

Total land demand for agriculture in China is projected to remain stable under the conditions of the global baseline scenario. However, other scenarios would bring relatively large differences. China has little margin in terms of available suitable land. Therefore, elements of China's Green Transition that influence land demand remain significant. They include agricultural productivity; the proportion of meat in the human diet; bioenergy production; and, in specific areas, urbanization.

In terms of land resources – soil, water, biodiversity – the worldwide context of China's Green Transition looks problematic. Pressures on land resources worldwide will allegedly become larger than anytime in human history (United Nations Convention to Combat Desertification, 2017). Keeping China's agricultural demand and production stable during the coming decades, while carefully retreating from overly high-input practices, would arguably be China's largest contribution to managing global land resources and the global food system. Specific risks emerge, in particular a very difficult combination of challenges in neighboring South Asia (Van der Esch et al., 2017). Opportunities emerge as well, such as China's leverage in Africa and potentially exportable experience in large-scale reforestation.

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