**<u>INTERNATIONAL LABOR ORGANIZATION</u>**

**CHINA CLIMATE CHANGE PARTNERSHIP FRAMEWORK MDG-F PROGRAMME**

# FINAL REPORT

# LOW CARBON DEVELOPMENT AND EMPLOYMENT IN CHINA


**Research Center for Urban development and Environment (RCUDE)**

**Chinese Academy of Social Sciences (CASS)**


**Nov 29 2009, FINAL DRAFT**

## Report Team

- **Research Team:**
  - ✧ Project Leader: Prof. PAN Jiahua
  - ✧ Project Coordinator: ZHENG Yan
  - ✧ Forestry Team：PAN Chenguang, KE Shuifa,WAND Cuihuai, et al.
  - ✧ Energy Team: ZHANG Anhua, CAO Leren, WU Jianjun, et al.
  - ✧ Steel & Iron Team: ZHAO Huiying, et al.
  - ✧ Input-output Analysis: ZHANG Ying
  - ✧ Comprehensive Analysis & Policy: PAN Jiahua, ZHENG Yan, ZHANG Ying，LV Runze, et al.

- **Reviewers:**
  - ✧ To be added

- **Contributors:**
  - ✧ Mm Constance Thomas
  - ✧ Mm QIAN Xiaoyan,
  - ✧ Ms Marja Paavilainen
  - ✧ Dr ZHANG Xubiao
  - ✧ Others (To be added)

## Acknowledgement

The research team should give thanks to all the team members since their hard working and intelligence for this report. We are also grateful for the organizations and individuals during interviews and field research for collecting date, sharing information and expertise.

The authors would like to give sincere thanks to the technical and financial support from International Labour Organization (ILO), from Mm Constance, Marja Paavilainen, Dr ZHANG Xubiao, Ms PAN Wei, Peter, Vincent, and other experts in China office and international team. Their support and help make our work goes well. Also the authors thank to Mm QIAN Xiaoyan and Mr LV Runze, and other experts from MOHRSS, they give informative suggestions during the whole work. Finally, We acknowledge the contribution of translators, they are Ms Dingding, Ms MAN Yanan, Dr LIU Hui, Ms XIE Qianyi, and some other contributors. The editing work is contributed by Dr ZHANG Ying, Dr ZHENG Yan, Dr ZHAO Huiying, Dr LI Kaifei. Thanks for their hard working in translating and editing during a tight schedule.

The research team will be responsible for the accountability of data and results, welcome further comments and suggestions to improve the final draft.

**Coordinator**: Ms ZHENG Yan

**TEL/FAX**： 00 86 10 8511 9035

**ADDRESS**： Room 609, No.10 XianxiaoHutong, Dongchengqu District, Beijing, 100005,China

# CONTENTS

**PRODUCTION TEAM** .......... **2**

**ACKNOWLEDGEMENT** .......... **2**

**EXECUTIVE SUMMARY** .......... **6**

**PART I. DEFINITIONS AND POLICIES** .......... **11**

1 Background .......... 12
2 Concept and Policy .......... 13
*2.1 Low Carbon Development* .......... *13*
*2.2 Low Carbon Economy (LCE) and Employment: An Overview* .......... *14*
*2.3 Practice of the Green Economy and LCE in Major Economies* .......... *16*
*2.4 China's Low Carbon Strategies and Practice* .......... *18*
*2.5 Key Industries Related to Low Carbon Development* .......... *19*
3 Methodology and Data .......... 24
*3.1 Research Framework* .......... *24*
*3.2 Analytical Methods* .......... *25*
4 General Analysis on Low Carbon Development and Employment in Major Sectors .......... 26
*4.1 Historical trends of Employment, Output and Energy Consumption of Major Sectors* .......... *26*
*4.2 Comparative Analysis of Carbon Productivity and Carbon Employment Rate in Major Sectors* .......... *30*
*4.3 Conclusion* .......... *34*

**PART II. EMPLOYMENT IMPACT** .......... **36**

1 Forestry Industry .......... 37
*1.1 Climate Change Impacts on Forestry Industry* .......... *37*
*1.2 Methods for forestry industry to promote low carbon development* .......... *39*
*1.3 Afforestation and Re-afforestation* .......... *43*
*1.4 Forest Ecological System Management* .......... *49*
*1.5 Forest Tourism* .......... *50*
*1.6 Conclusion and Suggestions* .......... *56*
2 Power Industry .......... 59
*2.1 Background* .......... *59*
*2.2 Coal-fired Power Industry* .......... *64*
*2.2.3 Overall Employment Effect of Coal-fired Power Industry* .......... *71*
*2.3 Wind Power Industry* .......... *72*
*2.4 Solar Power* .......... *86*
3 Basic Industry .......... 99
*3.1 Employment Effect of Basic Industry* .......... *99*
*3.2 The Iron and Steel Industry* .......... *100*
*3.2.1 The status quo and prospect of the development of iron and steel industry* .......... *101*
*3.2.2 Policies responding to climate change for China's iron and steel industry* .......... *102*
*3.2.3 The Impact of Low Carbon Development on Employment in Iron and Steel Industry* .......... *105*

*3.2.4 Policy Recommendations* ........ *109*
4 GREEN INVESTMENT ........ 111
*4.1 Identifying Green Investment and Green Industries in China's Economic Recovery Plan* ..... *111*
*4.2 Directions of the Flow of Investments* ........ *114*
*4.3 Analysis of the "Green Investment" Induced Employment* ........ *117*
*4.3.1 Energy-saving and Ecosystem Enhancement and Impact on Employment* ........ *118*
*4.3.2 Industrial Structural Adjustment and Technological Innovation and Impact on Employment* ........ *119*
*4.3.3 Rural Livelihood Project Construction（Biogas Digesters Project）* ........ *120*
*4.3.4 Conclusions* ........ *120*

**PART III. CONCLUSION AND RECOMMENDATION ........ 122**

1 CONCLUSION ........ 123
2 POLICY RECOMMENDATION ........ 126

**ANNEX 1: ABBREVIATION ........ 129**

**ANNEX 2: DATA MINING AND RESOURCES ........ 131**

**ANNEX 3: INPUT-OUTPUT ANALYSIS ........ 134**

# Executive Summary

Adaptation and mitigation are the two major measures to deal with climate change. To realize low carbon development, mitigation policy and low carbon technology are key approaches. Low carbon development is directed towards a low carbon economy through de-carbonization processes, aiming at sustainable development as well as tackling climate change. Industrial structure and energy structure will be readjusted in the process of de-carbonization and technology advancement. Policies will be introduced for phasing out less efficient power generation and for developing new technologies and new energy, leading to positive impacts of reduced emissions on different industries.

There are two major approaches to de-carbonization. One is through a structure of the economy with lower carbon, and the other is via an increase of cleaner energy in the energy mix, and to increase the deployment of low carbon technologies. Considering the fact that China is at the stage of capital intensive industrialization, there is only a limited scope or even impractical to some extent to reduce the share of energy/carbon intensive sectors in the economy, in a short period to a similar low level to some developed countries. Therefore, at present stage, low carbon development in China should be a relative instead of absolute, through promotion of energy efficiency and carbon productivity in individual industries by way of technology progress and policy incentives.

Since 2008, China, with great achievements made, has actively implemented the ideal of low-carbon development and pressed forward the policy of energy conservancy and emission reduction in tackling climate change and the financial crisis. In September 2009, President Hu Jintao addressed a speech entitled “Join Hands to Address Climate Challenge” at the United Nations summit on climate change and made it cleat that China would greatly develop green and low-carbon economy. Based on the emission reduction goal of the 11th five-year plan, China will make further effort to: first, to strength emission reduction and promote energy efficiency and to sharply reduce carbon emission by 2020; second, to development renewable energy and nuclear energy and to increase the proportion of clean energy consumption to 15%; third, to increase carbon sequestration in

forestry; forth, to develop and popularize climate-friendly technologies. In November 26th, just before the coming of COP15 of UNFCCC, China announced a voluntary mitigation target, which is to reduce 40-45% carbon emissions per GDP in 2020 on the basis of 2005. The quantitative target shows China's orientation of policies to realize low-carbon development in the future. These measures have profound and far reaching influence on China's green and low-carbon employment.

**Green employment** and **low-carbon employment** have a lot in common. For instance, they are both marked by low energy consumption, low pollution, high carbon efficiency, low waste and beneficial to environmental improvement. What's different from green employment is that, low-carbon employment covers the employment sectors which can promote the low-carbon development and alleviate climate change. Low-carbon development has different impact on output and employment in different industries by changing investment flow. The study categorized the employment effect in one industry into three aspects.

**Direct employment effect** is defined as jobs created in such sector to expand manufacturing when output increases; **indirect employment effect** is defined as jobs incurred by the production of inputs to the specific sector in its production process; **induced employment effect** refers to the sum of all jobs created during the production expansion.

Energy conservancy, emission reduction and ecological environment development are the major ways of promoting low-carbon development in China. Although energy conservancy and emission reduction have negative impact on employment in industries related to fossil energy, the technology advancement and cost reduction brought about by energy conservancy and emission reduction may be conducive to the long term development of the economic system. Ecological environment development has positive impact on employment in forestry sectors, including forestation, reforestation, ecological system management in forestry, forest tourism and so on.

Based on documents from home and abroad, comparative research and the method of input-output analysis, the study calculated the employment effect lead by policies of low-carbon development in some major industries in China. As shown in the results, in general, the low-carbon development has positive employment effect on major industries in China. (Results shown in Table 1)

**Table 1：Employment effect analysis of low-carbon development（Unit：10,000 people）**

| **Sector** | **Sub-sector** | **Direct employment** | **Indirect & Induced employment** |
| --- | --- | --- | --- |
| | | **2005～2020** | **2009～2020** |
| **Forestry** | forestry plantation and re-plantation | 760 | 1108.8 |
| | Management on sustainable forest | 16.69～20.86 | 5.4～6.75 |
| | Forest tourism | 315.4 | 361.6 |
| **Electricity** | thermoelectricity | -23.0 | 78.25 |
| | Wind power | 50.08～73.45 | 142.51～206.62 |
| | Solar power | 18.64 | 62.35 |
| **Infrastructure** | Steel Industry | -24.86 (2005～2011) | -- |
| **Total** | | **1112.95～1140.49** | **1758.91～1824.37** |
| **Green investment（2008-2010）** | 56.7 | 151.7 | 151.7 |
| | 92.0 | 141.9 | 141.9 |
| | 2.63 | 6.36 | 6.36 |
| **Total** | | **151.3** | **300.0** |

The study illustrates that the ripple effects of low-carbon development on employment is clearly distinct. From 2005 to 2020, the total net direct effect of employment in the three industries (Forestry, Power, Iron & Steel) would reach at 10 million persons, as well a direct and induced employment of 18 million jobs would be created at the same period. As thermoelectricity and steel industry lose jobs because of energy conservancy and emission reduction policies and phasing out of backward production capacity, forestry and clean energy industry--as typical green industries--have shown huge potential of low-carbon employment. In addition to organic growth, forestation, forest tourism, wind power and solar power could have a series of expansion effects on the whole industry chain and give a boost to employment. Furthermore, the investment in green industries posts 15% in the 4-trillion stimulus package, which will create 4.5 million job opportunities in the society. Given the situation when the domestic demand needs to be expanded, the industry structure needs to be adjusted and the economic growth pattern needs to be transformed, the rise of proportion of green investment will not only beef up low-carbon development, but play a dual role in promoting economic growth and improving employment.

In order to promote low-carbon development and achieve the low-carbon employment target, following suggestions are made based on the conclusion of this report:

**Low-carbon development is able to give a boost to low-carbon employment**: different industry's contribution on employment and output is varied. Generally speaking, the indirect effect of low-carbon development is more obvious than its direct employment effect. So the great potential in low-carbon employment can be tapped by adopting low-carbon development policies such as energy conservancy, emission reduction, eco-development and optimization of industry structure.

**Low-carbon service industry can be exploited to optimize the industry structure:** considering the dependency on energy of different industries and the upgrading of industry structure, China should step up developing tertiary industry, especially the one that offers R&D support to the industry like manufacturing and consumption service industry that boosts domestic demand. In the meantime, the high added-value first industry (e.g. eco-agriculture, energy cropping forestry, eco-forestry, etc.) should also be encouraged to develop to achieve the dual target of employment and low-carbon economy.

**Green investment should be expanded for more job opportunities**: the 4-trillion stimulus package is relieving the pressure facing China's economy, but China has not entered into economic recovery marked by growth of employment as most investment flows into infrastructure projects, such as transportation, construction, etc. Once "Carbon Lock-in" takes effect, the potential of emission reduction will be compromised. At present, the investment in the green industry that is associated with low-carbon development in the 4-trillion stimulus package only accounts for 1/5. We need to increase the proportion of investment in the green industry and build up a structure that puts employment first so as to set a solid foundation for a structure-optimized low-carbon economy.

**Some pilot programs can be carried out to promote low-carbon employment first in some regions and then extended to other areas**: promoting low-carbon employment needs to take into account the specific conditions in different industries and regions, and it also requires the support of policies. Given that low-carbon economy is a new model of economic development, we do not have much precedent experience to learn from other countries. Therefore, we suggest that we carry out pilot programs in some regions and in some representative enterprises/industries based on related studies. With that experience, supporting policies of low-carbon employment can be formulated.

# PART I. DEFINITIONS AND POLICIES

# 1 Background

The climate change has become a global challenge and a focus for global community in achieving for sustainable development. The Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC) presented more certainty information and evidences for climate change. AR4 also pointed out that it would be less opportunity cost if taking earlier action in mitigation for reducing the risks of global warming. Stern Review[1] on the Economics of Climate Change, which issued by UK Government in October 2006, warned that cost of inaction for climate change would be between 5% and 20% of GDP per year. The Stern Review also points to the need for a transformative increase in the scale of international finance flows for a low carbon economy.

To tackle climate change and its pressure on sustainable development, on international level, *UNFCCC* and *Kyoto Protocol* was established based on principle of common but differentiated responsibility. On national level, a number of countries have realized the necessity to cut down economic system's reliance on fossil fuels and assure development with low carbon emission. In Feb, 2003, British government first put forward the notion of low carbon economy in the "*Energy White Paper: Our Energy Future—Creating a Low Carbon Economy*", and pointed out the technical feasibility and reasonably economic practical of developing low carbon economy. Later in 2007, climate change strategic framework has drawn a long term picture of global low carbon economy, and low carbon economy has taken as the same importance to human development as the first industrial revolution and. The concept of low carbon economy aroused interest to tackle climate change with low carbon development globally. Japan determined to build low carbon society. Chinese cities as Shanghai, Baoding, and Jilin have taken some initiatives to develop low carbon economy.

Low carbon development will have a prominent impact on global employment. As we know, major measures to tackle climate change include adaptation and mitigation. Low carbon development is mainly focused on policy and measures for mitigation, including prioritizing economic structure, deployment of low carbon technology, improving energy efficiency, etc. Low

[1] Stern Nicolars, *Stern Review on the Economics of Climate Change*, Cambridge University Press, 2007.

carbon development is a development path which realizes low carbon economy through de-carbonization process, aiming at sustainable development as well as tackling climate change. In the process of de-carbonization, employment would have been effected in numbers and structure accompanied with changes in industrial impacts caused by low carbon policies as phasing out less efficiency equipment, developing new technologies and low carbon energy.

China has paid more attention on low carbon development. The Energy Saving and Emissions Reduction Strategy is a key policy in achieving for low carbon development. The policy proposed in the "12$^{th}$ Five-Year Plan" which requested a 20% reduction in energy intensity (energy consumption per GDP) in 2010 on the basis of 2005. Considering the policy would have a potential impact on China's employment in different sectors, the research will focus on the relationship between low carbon development and employment promotion in China. The Policy implications will be based on the modeling analysis.

The main objectives of the research project are:

1. to study the current status and future trend of low carbon development and green employment through analysis of empirical data and quantification;
2. to estimate the number of the job created and lost by projection in newly emerging industries and established sectors;
3. to give policy recommendations for promotion of low carbon and green employment for the overall objective of sustainable development in the context of China.

# 2 Concept and Policy

## 2.1 Low Carbon Development

The term of "low carbon economy" emerged since late 1990s with a growing attention on global climate change. A common accepted definition in China is "an economic form with low energy consumption as well as low pollution and emission[2]. Some hold that *A low carbon economy is*

[2] Zhang Kunmin, Pan Jiahua, Cui Dapeng, 2008, On Low Carbon Economy, China Environmental Science Press

*"low greenhouse gas emission economy" or "low fossil fuel economy*, it has been regarded as *"the only way towards achieving sustainable development that meets the challenges of energy resources, environment and climate change"* [3].

Low carbon development is a development path which realizes low carbon economy through de-carbonization process, aiming at sustainable development as well as tackling climate change. There are two different perspectives to understand low carbon emission.

- Fossil energy consumption: it requires absolute reduction of a country's total emission;
- Energy efficiency: it's relative low carbon development through improving the carbon productivity and the decline of energy intensity.

In a short term, a nation can achieve low carbon emission through enhancing energy efficiency and carbon productivity without change much its energy and industry system. While in a long term, technology advancement can facilitate the reduction of emission through policies and measures as clean energy substitution and low carbon technology employment. Therefore, we take the low carbon development as an increasing carbon output in the process of de-carbonization, which means much more output with less input of natural resources and energy consumption in the whole economy.

Under the threat of Financial Crisis the world suffered since 2008, some major economies, like USA, China and Britain, have taken efforts to recover by the way of green investment which aims to both low carbon development and green employment.

## 2.2 Low Carbon Economy (LCE) and Employment: An Overview

The development of LCE will inevitably promote job creation and the job market by means of optimizing or upgrading the industrial structure. In the long run, the key driving factor of developing LCE is to promote technological advancement, including improving the energy use efficiency and developing renewable energies. As a rule, the development of LCE will produce a direct (negative or positive) impact on the job market in the field of energy related industries, but will have an indirect impact on the job market on the other sectors, which is more positive

[3] China Council for International Cooperation on Environment（CCICED）, Low Carbon Economy: International Experience and China's Practice, Dec 2008

especially in some induced and emerging sectors.

The policies and measures of climate change mitigation affect the employment in both positive and negative ways.

**(1) Positive impacts**

- Mitigation of climate change requires improving energy efficiency. In Europe, millions of jobs are created while energy efficiency is enhanced by 20%, which would be also the same with China.
- Renewable energy policies cannot only mitigate environmental destruction but also create great chance for green jobs. According to "the China's Eleventh Five-Year Plan for Renewable Energy", China has set a target to increase the proportion of renewable energy from 5% to 10% ~ 15% in the total energy consumption during next 10 ~ 20 years, which will actively encourage and boost the development of manufacture, installation and maintenance of equipment to creates a series of job opportunities in hydro power, wind power and biomass energy.
- Energy Saving and emissions reduction need financing and investment, so the employment in finance will be spurred. For example, China is one of the main beneficiaries of CDM in international carbon market. In respect that Chinese energy consultation, negotiation, auditing, investment and management is underdeveloped, it will become an industry with the huge potential.
- "Low-carbon technique" refers to electricity, transportation, architecture, metallurgy, chemical engineering, petrifaction, automobile and so on. China has paid more attention on low carbon economy, which will attract a large amount of professionals and workers with the development of these sectors.
- Forestry and ecological protection can provide lots of job opportunities. China has carried out many policies for forestry protection and conservation, and the employment demands in the fields of forestry, gardening, forest management, ecotourism are increasing.

**(2) Negative impacts**

- The development of new techniques and green industries has high demands for technical staffs, but as a developing country, China has many less-educated labor forces. It is a disadvantage for China's labor transformation and would reduce the employment opportunities for many low-tech labors.

- The policy of energy saving and emissions reduction will influence employment in some industries and enterprise in some regions. Many medium or small sized enterprises which are resources-dependant and energy-based and not up to standards will gradually close down, which will shrink some industries and result in structural unemployment. It will take profound influence on many traditional industrial cities in western areas, for example, some low-end technicians in the field of heavy industry, machine manufacturing, iron industry, coal industry, architecture, automobile and coal-fired power industry may lose their jobs during the technique upgrade.

As a whole, climate change would pose positive impacts on employment, given that the policy of climate change mitigation can be put into practice reasonably and effectively.

## 2.3 Practice of the Green Economy and LCE in Major Economies

The United Nations Environmental Program (UNEP) proposed "Global Green New Deal-UNEP Green Economy Initiative[4]" in October 2008 in response to severe world financial crisis. This initiative advocated increased investment in cleaner technologies in each member state's economic stimulation package. By means of developing clean energies, energy efficiency buildings as well as organic agriculture, this initiative expected that the tendency of high-energy consuming and the high-polluting mode of economic growth could be reversed and the low-energy consuming, low-pollution LCE could be in place.

Some countries have understood the potential of developing LCE and are now acting actively to realize job generation on LCE. The Obama's administration formulated the "Green Recovery Program" [5], with developing new energy as the centerpiece in a bid to create more job

[4] UNEP, Feb 2009, "Achieving for Global Green New Deal", http://new.unep.org/Documents.Multilingual/Default.asp?DocumentID=562&ArticleID=6079&l=zh&t=long

[5] The programme planed a 100 billion investment during 2 years in green infrastructures, including: energy-saving building, mass transport, smart power grid, wind power, solar power, second generation bio-fuels, etc. In 2009, Obama administration issued a 787 billion dollars investment plan, among which

opportunities by capitalizing on the spillover effects of investment in new energies. It is estimated that for each 1 billion investment in new energy, 20,000-30,000 job slots could be created for Americans and in the meantime, 600,000 tons of greenhouse gas emissions could be reduced[6]. In light of the prospects of renewable energy development, the University of California at Los Angeles (UCLA) made a forecast of the job creation, it believed that by the year 2020, the American renewable energy industry could spawn as many as more than 1.3 million job opportunities[7].

The European countries always have a tradition of valuing the decent work. In 1999, the DGB and some environmental NGOs, together with the Enterprise Federation set up the "Alliance for Work and Environment" programme with the purpose of increasing the environmental protection and expanding green job opportunities through improving building efficiency. During the period from 2001 to 2009, the German government has provided this project with nearly $10 billion and created more than 200,000 job opportunities. It has also realized the target of reducing 2 million tons of carbon dioxide emissions[8]. To mitigate the climate change, economic crisis as well as the unemployment, the German government will formulate an economic stimulation package with the total value peaking at US$11 billion in an attempt to increase building energy efficiency, which would create more than 600,000 job opportunities. In the meantime, this package is also expected to reduce the annual carbon dioxide emissions by 3 million tons.

The Korean government also formulated the Green New Deal Program valued at $38 billion (taking up 1.2% of its GDP), with the purpose of providing the whole country with catchment area management, public transport network, information infrastructures, water conservancy projects, green cars and clean energy, recycling services, reforestation and , efficient energy use in school buildings and rural areas. It is estimated that this program is expected to create more than 500,000

---

accounted for 8.7% of its GDP and about 80 billion dollars are related to renewable energy, such as 20 billion dollars for tax and subsidies in the coming 10 years.

[6] PERI，Center for American Progress, "Green Recovery-A Program to Create Good Jobs and Start Building a Low-Carbon Economy", Sept. 2008, www.peri.umass.edu；UNEP，"Achieving for Global Green New Deal"http://new.unep.org/Documents.Multilingual/Default.asp?DocumentID=562&ArticleID=6079&l=zh&t=long

[7] Max Wei,2009，"A Great Potential in Job Creation: a US Perspective"，China Green Jobs Experience Sharing Meeting. 30- 31, March, 2009, Beijing

[8] Warner Schneider, DGB, Germany, "Alliances for Work and Environment in Germany"，China Green Jobs Experience Sharing Meeting. 30- 31, March, 2009, Beijing

job opportunities in the field of water treatment, forest management and energy efficiency buildings.

Additionally, in March 2009, the European Union also announced that it would make an investment of 105 billion Euros to finance the development of green economy as a way to stimulate the job and economic growth. Japan further announced that it would expand the value of its green economy to $1080 billion by 2015. In China's $586 billion investment program, about $140 billion (nearly 2% of its total GDP) will be used as "green" investment and $17 billion would be invested in the renewable energy.

## 2.4 China's Low Carbon Strategies and Practice

As GHG reduction is consistent with Chinese energy saving and emissions reduction policy, Chinese government has successively enacted a series of policies and legislation measures on the basis of national conditions. Energy saving has been the inner incentives for enterprises to reduce cost, which also has been pushed by central government since 1980's. From 1990 to 2005, China's energy intensity has a decline of 46.6.%, which equaled to 1.8 billion CO2 reduction. China has a coal-based energy structure, with only 7-7.5% of renewable energy. At present, China has actively promoted the deployment of wind power, solar resources, hydro-power, biomass and nuclear energy. Meanwhile, China has also taken serious on the huge potential of forest and eco-system on increasing carbon sink and expanded the investment on afforestation/reforestation.

Since 2006, Chinese government has speed up the energy saving and emission reduction under the background of environmental protection and mitigation for climate change. From then on, China has enacted "China's National Programme on Climate Change", "the Development Plan of Renewable Energy in the Medium and Long Term", "the Eleventh Five-Year Plan for Renewable Energy", "Energy Saving Law", "Renewable Energy Law" and other relevant laws, and "Recycling Industries Promotion Law" and " Energy Law" are coming into being to implement as soon.

In the National Energy Saving and Emissions Reduction Meeting in May 2007, Chinese Premier Wen Jiabao represented the main measures to save energy and reduce emissions. (1) It is the top priority to limit the overfast development of industries with resource and energy high consumption, high pollution and high emission, such as electricity power, iron and steel, nonferrous metal, building materials, petroleum manufacture and industry; (2) Try to eliminate the less efficiency capacity in the power industry, iron and steel, nonferrous metal, building materials, electrolytic aluminium, ferroalloy, coal, coke, paper making and food; (3) To popularize the application of energy saving products; (4) To develop recycling industries including the comprehensive usage of mineral resources and solid rubbish, and the recycling of renewable resources and water resource; (5) To promote enabling environment so as to eliminate the institutional obstructions of energy saving and emissions reduction; (6) To increase the financial inputs from government, enterprises and the whole society. The above measures provide the priorities for the transformation of industrial structure and economic growth pattern, and will have big influences on the change of employment in some relevant industries, such as power industry, iron and steel, renewable energy and so on.

China has made a big progress in implementing energy saving and emissions reduction. From 2006-2008, energy consumption per GDP has decreased 10.08%. We would expect an promising prospect for employment during the process of structural transformation technology advancement.

## 2.5 Key Industries Related to Low Carbon Development

The united nations Environment Program (UNEP) and the International Labor Organization (ILO) released a report entitled “Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World”, outlining six areas that stand a better chance of realizing lower greenhouse gas emissions, resource conservation as well as job promotion. These areas include the following economic sectors: renewable energy, buildings and construction, transportation, basic industry, agriculture, and forestry. These key areas may not only have the greatest potential for reducing greenhouse gas emissions, but only have the maximum potential to increase green employment. Among these, forestation, renewable energy, transport, green buildings, recycling may promise the greatest degree of job growth.

**1. Forestry**

Without any doubt, forest is the largest carbon sink and the most economical carbon absorber. According to the Human Development Report of 2007-2008, by the year 2005, the total carbon sink volume of China's forest was about 6.10 billion tons, taking up 2.16% of the total carbon sink volume of the world. Since 1980, the Chinese government has given huge financial input into forest development and established a series of key forestry projects as a way to expand the size of China's forestry. Consequently, China's forest carbon sinks expanded considerably. In 2007, China published its National Climate Change Program, stressing the need of afforestation and reforestation in an attempt to best perform the functions of forest's carbon sink capacity. It is estimated that during the period of 1980 to 2005, China's forest planting efforts enabled China's forests to absorb 3.06 billion tons of carbon dioxide. According to China Forestry Development Strategy, by the year 2050, China's forest coverage rate will be up to 26% of its total geographical area and as a result, the total carbon sink volume of China's forest reserves will shoot up by 90.4% on the basis of 1990.

Many forest related industries cut cross the agricultural, industrial and tertiary sectors. The role of forestry in employment can be summarized as follows: (1) forest by-product industries: It includes timber manufacturing and processing, agro-forestry like the flower, bamboo, food and medicine industries, etc., undoubtedly, which can best tap the employment potential on a wide scale. (2) Afforestation: China is now doing six major projects on forestry. It's estimated 228 million job opportunity would be induced by 76 million hectares new afforestation/reforestation task during the following 10 years. (3) Forest Tourism: China's ecotourism and forest tourism witnessed a rapid development with the total number of doing forest tourism increased by 30%.

**2. Energy Sector**

Constrained by the practice of energy saving and emission reduction, the employment situation manifests greater variance with the different fields of the energy sector. The employment in the traditional fossil fuels such as thermal power generation could be negatively impacted, while employment in the new tech industries like the renewable energy development, carbon capture and storage could be positively impacted.

This point can be better explained by looking at the power generation industry. (1) Thermal power generation: This particular industry is reformed or innovated to increase its energy efficiency in the course of low carbonization. As a result, the closing down of small units of coal-fired power plants with small capacity and low efficiency will inevitably increase the economic efficiency of the thermal power generation but downside of this move to decrease their job positions. (2) Hydropower, wind power and solar Power: All of these three types of energy belong to zero-carbon energy. Among these, the wind power plants and solar power plants cannot absorb much labor in itself, however, they can possibly create more job opportunities in the down stream and up stream sectors like equipment manufacturing and technical service. (3) Biomass Energy: This type of energy concerns the development and research of fuel forest and bio-energies, the processing and recycling of crop straw, the power generation by means of biomass as well as the power generation equipment manufacturing. As related to different chains of industry, it has the best potential for job creation. (4) Nuclear Power: This type of energy is also a zero-carbon emission energy and can produce direct and indirect employment effects.

**3. Iron and Steel Industry**

The iron and steel industry is particularly high-polluting, high-energy consuming as well as high-GHG emitting. The iron and steel industry is also a typical industry that needs the maximum technological input. Generally speaking, the low carbonization has a negative impact on employment in iron and steel industry.

China is the largest producer and exporter of iron and steel products in the world. The National Iron and Steel Revitalization Program published in January 2009 stressed the need to push forward China's iron and steel industry by means of controlling its total number, eliminating the low-production plants, reshuffling and innovating the existing ones. However, the serious implementation of energy saving and emission reduction will impact the iron and steel employment in two ways. One the one hand, by curbing the expansion of the traditional iron and steel industry, China will inevitably self-limit the number of employment in this particularly field. On the other hand, by taking advantage of advanced technology, some new job opportunities can be created within the traditional iron and steel industry. However, the iron and steel industry, by increasing its productive efficiency via advanced technology, will significantly push forward the development of its supplementary services and consequently create more job opportunities.

## 4. Recycling Industry

Renewable resources form an important component of the recycling economy. The recycling economy is featured as reuse, reproduce, and recycle of resources and energy. The specific form can be described as “resource-product-renewable resource” and “production-consumption-recycling”. As early as 1980s, China has been actively pushed forward the comprehensive utilization resources program. Now, the utilization rate of the industrial wastes (waste gas, waste water, solid waster) in China has been up to the level of 60%[9]. However, the recycling of renewable resources has not actually been a mature industry. Compared with the developed countries, China’s comprehensive utilization rate of resources is only 10%. Considering the huge disparity in technological levels and resource consumption of each enterprises, together with the increasingly shortage of resources supply, recycling is none other than the most important avenue to realize the recycling economy and low carbonization.

In a series pilot projects on recycling published in 2005, the recycling and reproducing system for wasted metals, plastics, papers, and waste electronic appliances and so on occupied an important place. It is now widely believed that China’s resource recycling and reutilization is a promising field which may promise greater employment opportunity, either in a direct way or indirect way. According to some estimates, the total volume of recycling resources totaled 158.1 million tons, including 40 million tons imported from other countries. The gross value from processing the recyclable resources totaled 350 billion RMB yuan, a 22% increase compared with that of 2005. In China in 2008, 20% of the non-ferrous metals fall into the category of recyclable metals. In any country today, the resource recycling and reutilization represent a complete chain of industry that cut cross the tertiary services and manufacturing. Currently, it’s estimated that China’s resource recycling services employ more than 10 million people, among which, 6 million are migrant workers from the rural areas. It means that most of them are temporary workers with a decent labor condition. This situation poses two problems. On the one hand, these temporary workers are not provided with labor safety devices, and furthermore, their job security is not guaranteed; on the other hand, the hand-treated work style lead to the low efficient resource use as well a

[9] China Resource Recycling Association，“promoting industrial energy saving and comprehensive utilization by the way of implementing recycling economy”， http://www.crra.org.cn/listDetail.aspx?INAC_PID=INACID200809021508141347&INAR_ID=ARID200901231012077368&INAC_ID=INACID200809081753304182

considerable environment degradation. It is highly imperative that these temporary workers be trained and government policy support be in place so as to push forward the professionalization of the recycling services[10].

[10] In June 2006, China Resource Recycling Association organized a training for peasant recycling workers in Beijing, some qualified trainees have been endowed a certificated. The training project endeavored to educate the peasant workers to know about environmental protection, management skills, operation security and socio-responsibility, and son on.

# 3 Methodology and Data

## 3.1 Research Framework

The current research focuses primarily on the impact of low carbon development strategies (including energy saving and emission reduction, renewable energy strategy, eco-forest projects, etc) implemented in the fields of forestry, energy, iron and steel. The research will be carried out in two separate phases. The first phase has a focus on the thermal power generation and carbon sink forestry; the second phase will focus on industries of renewable energy, iron and steel industry, etc. The framework of this research is as follows:

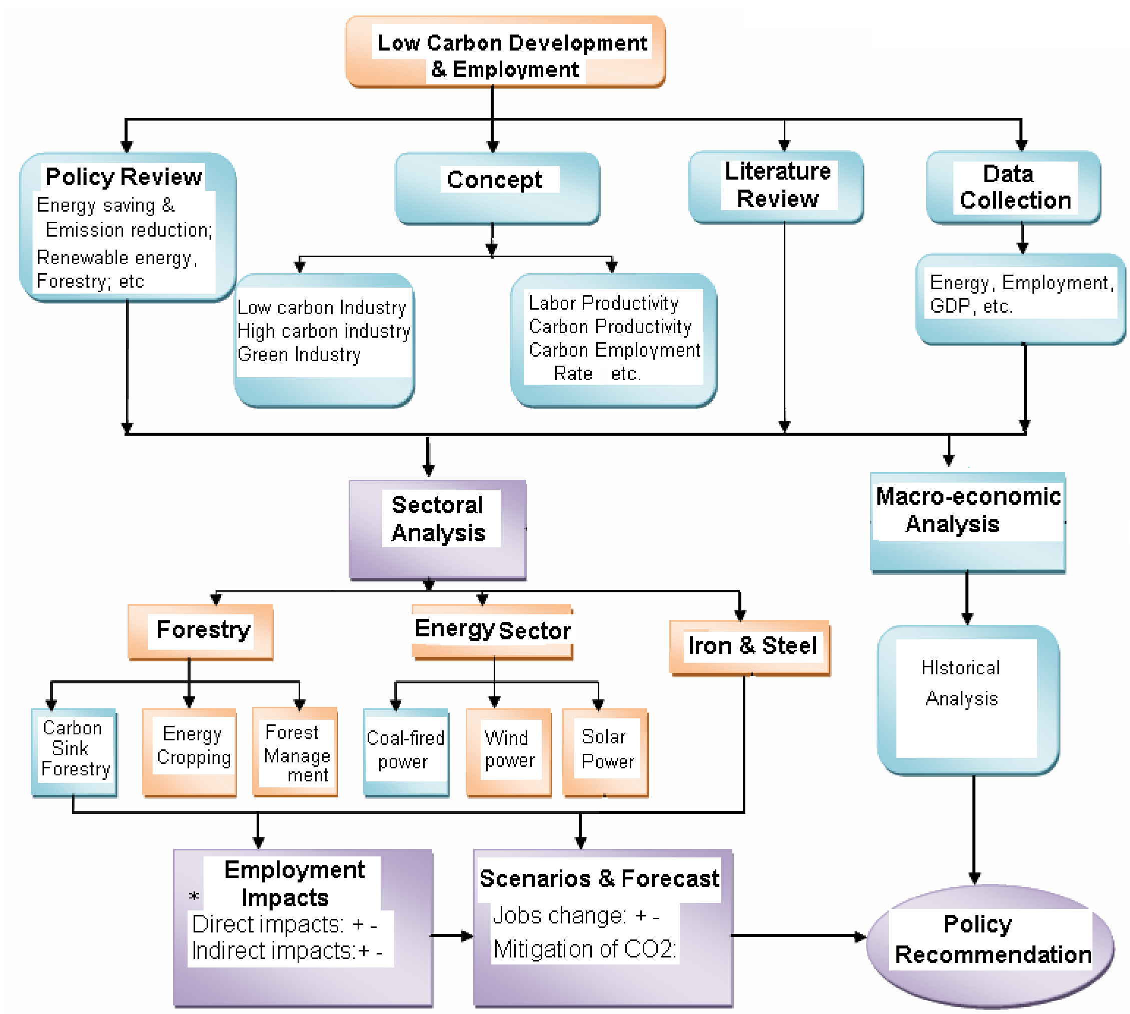


**Figure 1-1: Analytical Framework**

### 3.2 Analytical Methods

Based on the literature available, we believe that the employment impact can be approached in two ways. One is the macro-framework (input-output) analysis, historical trend analysis by employing econometric tools and field investigation, etc. In terms of research objectives, it can be grouped into the top-down approach which is what we understand as macro-framework analysis, and the bottom-up approach which is what we understand as field investigations. This study trend analyzes the fluctuations of energy efficiency in major industries (like agriculture, industry, construction and transport, etc) by employing the econometric model. This study further makes an estimate of the impact on employment in these major economic sectors associated with energy saving and emission reduction. To ensure the reliability of data, this researcher did a thorough literature review and a field investigation to predict the employment impact.

In sum, the employment effect will be addressed in two levels. On the first level it will focus on the direct effects on employment driven by specific environmental policies(e.g. the rising energy prices, the application of new technology as well as investment program on renewable energies, etc). On the second level, the indirect effects will be based on a particular industry and explored its impacts on the whole socioeconomic system and other related economic sectors. This research, however, looks at the first level employment effects.

# 4 General Analysis on Low Carbon Development and Employment in Major Sectors

Based on the availability of data, this study approaches the research topics in the following fields: (1) agriculture (farming, forestry, animal husbandry, side-line production and fishery); (2) mining; (3) manufacturing; (4) power, heat, gas and water production and supply; (5) construction; (6) transport, storage and telecommunications; (7) wholesale, retail, dining and lodging; (8) other services[11]. The researcher hopes to discriminate the low carbon industry from the high carbon industry by analyzing the carbon productivity, carbon employment rate as well as energy intensity. The study also hopes to suggest some feasible policies and objectives by examining the differential impacts on low carbonization of each type of industry.

## 4.1 Historical trends of Employment, Output and Energy Consumption of Major Sectors

### 1. The Employment and Output Changes in China's Major Sectors

The population in China engaging in economic activities has risen from 101 million in the early 1950s to 780 million in the 2007. During this period, the structure in China's job market also sees notable change amid the rapid urbanization and industrialization process. Importantly, the proportion of labor invested in agricultural sector in China has decreased from 80% in the 1950s to 40.8% in the present time, about a 50% fall. In the meantime, the proportion of employment in industry and tertiary sector has risen from 7.4% and 9.1% in 1952 to 26.8% and 32.4% in 2007 respectively. Starting from 1994, the amount of labor employed in the tertiary sector surpassed that of industry and it has shown a robust growth (as seen in the figure 2-1).

[11] Note: the first industry is Agriculture, including farming, forestry, animal husbandry, side-line production and fishery; The secondary industry includes mining; manufacturing; power, heat, gas and water Production and supply; construction. The tertiary industry includes transport, storage and telecommunications; wholesale, retail, dining and lodging; and other services. The other services include Finance; Real Estate; Information Technology and Software services; Tenancy and Business; Scientific Research and Technical Services; Water Conservancy, Environmental Protection and public infrastructures; Residential Services; Education, Culture, Sports and Entertainment; Sanitation; Social Security & Welfare; Public Management & Social Organizations. There are two types of services among the tertiary industry, one is producer services, another is consumer services. The producer services are dependant on the manufacturing industries and provide human capital and knowledge as inputs for manufacturing process. China's "Eleventh Five-Year Plan" proposed to develop the following six major producer services: modern logistics Industry, international trade, information services, finance and insurance, a modern convention and exhibition industry, intermediary services.

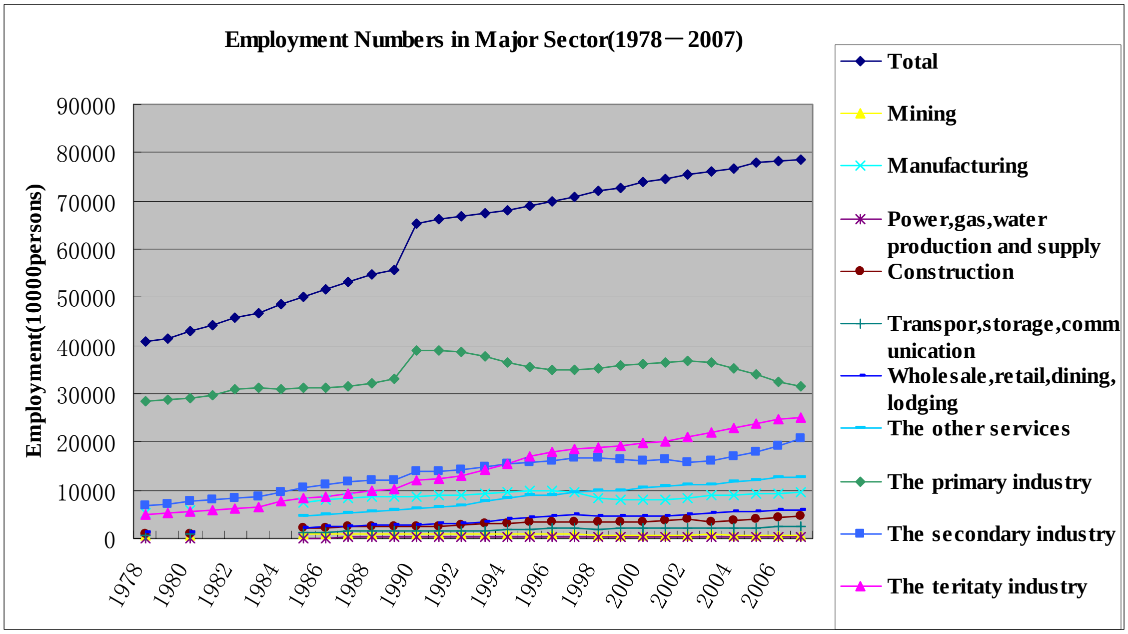


**Figure 1-2: Employment by Sectors from 1978 to 2007**

As Figure 1-2 and Figure 1-3 show, the proportion of the employment in each sector to the output displays a very different pattern in the whole economic landscape. Evidently, the proportion of the employed in agriculture to the output has been decreasing year by year, while proportion of the employed in the secondary industry has fallen below the level of 30%, its output maintains a half of the total national output. The contribution of tertiary sector started to surpass that of agriculture in mid-1980s and has always been maintaining a rapid increase. Currently, the output of tertiary sector maintains at the level of 40% of output. Plainly enough, with the progress of industrialization and urbanization, China's economic structure has witnessed a shift from production-oriented towards service-oriented direction. Except for those producer services like financial, insurance, real estate has a rapid growth so as to meet the needs of manufacturing industry, it is particularly notable that with the rising living standards of the Chinese people, some consumer services like retail, tourism, culture and recreation, etc have sprung up.

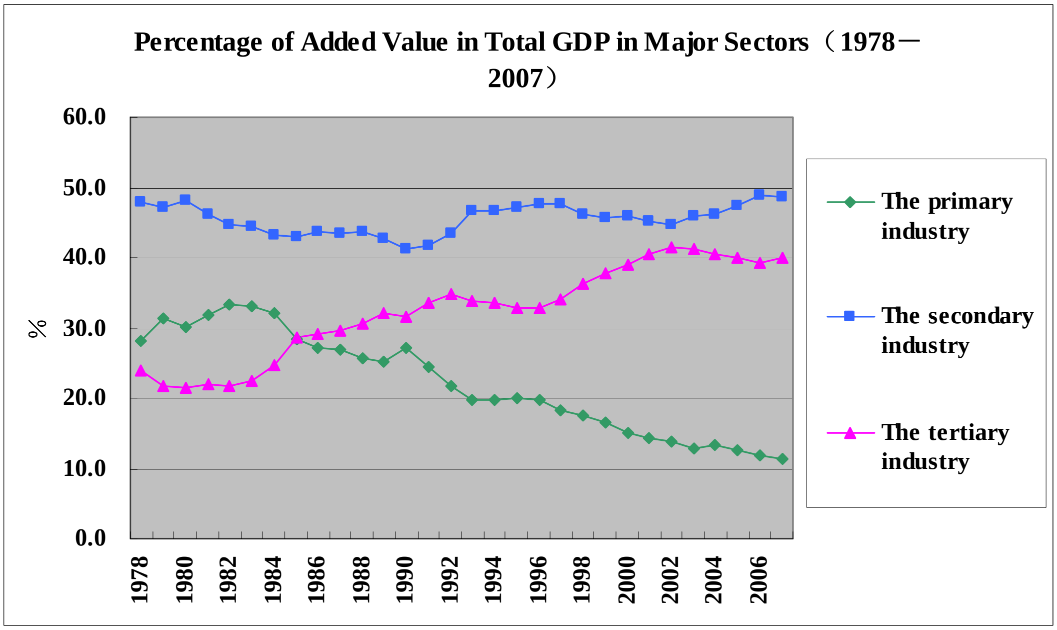


**Figure 1-3: Percentage of Added Values in total GDP of three Major Sectors (1978－2007)**

Figure 1-3 displays the rise and fall of the added value of the three major sectors. It is clear that the industrial output forms a overwhelming high proportion in China's GDP, suggesting China is still in the mid-and late stage of industrialization.

## 2. Labor Productivity in Sectors

As seen from figure 1-4, except for the "other service", the labor productivity in most of industries take a rise during the past decades. Among which, mainly benefit from the drive of technology advance, the basic industry ranked the top of the increase rate with 9 times higher in 2007 than that in 1985. The lower productivity in service industry may display the fact that less developed in some high-added-value sectors like technology deployment, finance and insurance, consultation, cultural and entertainment, and so on.

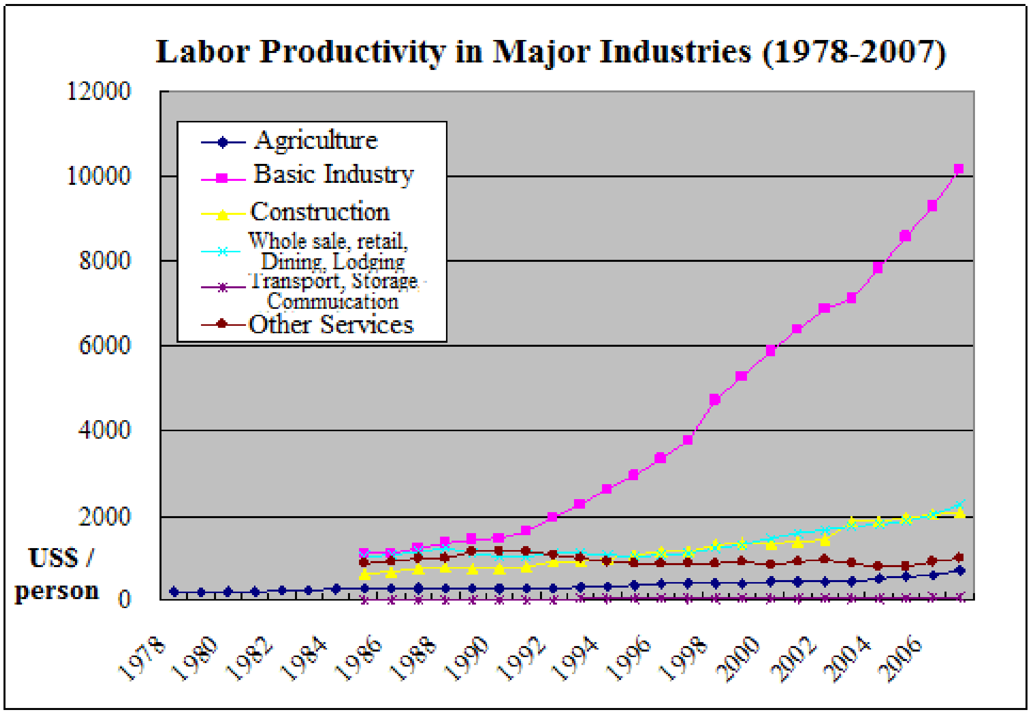


**Figure 1-4: Labor Productivity in Major Sectors in 1978－2007**

### 3. Energy Consumption in Different Sectors

Seen from Figure 1-5, the amount of energy consumption from the 1980s witnessed a steady increase and this increase became more notable since 2002. This is because the proportion of heavy industry increased in China's industrial component and further raised the demand for energy supplies. The result was that basic industry became the largest energy consumer compared with other economic sectors, and basic industry is also the largest pollutant and carbon emitter.

Relative to the amount of energy consumption of other sectors, the amount of energy consumption consumed by basic industry takes up more than 70% and manufacturing takes up more than 80% the consumed energy in industry. However, there is one importance: the bulk amount of energy consumption in developed countries is concentrated on building and transport while in China, the largest share of energy use is in industry and the percentage of residential use is quite low. For example, the amount of industrial energy use in the US takes up only 20% of all energy use and Japan 30%. However, these facts do support the notion that China is indeed a "world factory" characterized by high energy consumption.

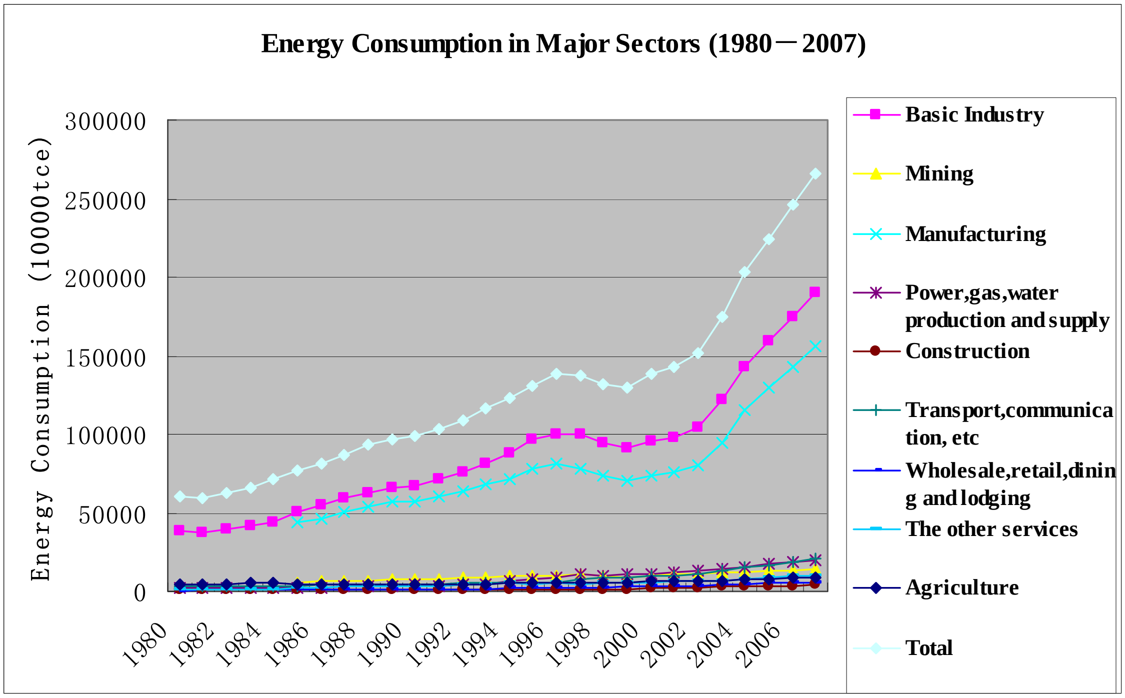


**Figure 1-5: Energy Consumption of Major Sectors from 1970-2007**

## 4.2 Comparative Analysis of Carbon Productivity and Carbon Employment Rate in Major Sectors

Generally speaking, economic development necessitates the input of the following elements: capital, labor, energy and technology. Tons of studies have delved into the differential contributions of energy, capital and labor to economic growth. Some studies have shown that there exists a relationship of replacement or complementation among energy, capital and labor[12][13][14]. The policy implications lie in the fact that if the relationship of replacement does exist between the energy and non-energy element (capital and labor), then the economic growth of this particular sector can maintain its normal growth by making the best use of capital and labor should the energy price go up or energy saving and emission reduction strategies be implemented. On the

[12] Yang Zhongdong, 2007, "Study on the Substitution Effects of Energy in Manufacturing Industry", ***Contemporary Economic Sciences***, May, Vol.29, No. 3

[13] Murry, D.A. ; Dan, G.D.，1990 Sep，The energy consumption and employment relationship: A clarification，***Journal of Energy and Development*** ; Vol: 16:1

[14] Tsangyao Chang; Wenshwo Fang; Li-Fang Wen， Energy consumption, employment, output, and temporal causality: evidence from Taiwan based on cointegration and error-correction modelling techniques, ***Applied Economics***, Volume 33, Issue 8 June 2001 , pages 1045 - 1056

other hand, should there be a complementary relationship between the energy element and non-energy element, then in a short term, the rising energy opportunity cost caused by stricter environmental polices and regulations may drive down the investment in energy and consequently other inputs like labor force and capital, thus decreasing the output of this sector and demands on jobs. However, in the long run, the deployment of new technology and efficient equipment will reduce the energy cost and improve the economic output which could correspondingly reduce other inputs as labor force in per unit of energy.

Based on the above analysis, primarily on the comparative study between carbon productivity and carbon employment rate in major sectors, as well as the employment in major economic sectors, and the proportion of output to energy consumption, we can detect the interrelationships among these indicators and further reveal the possible effects of ESER (energy saving and emission reduction) policy on energy consumption, output and employment of major sectors.

## 1. The trend of China’s Low Carbon Development

Figure 1-5 embodies the changing pattern of China’s carbon productivity in history. In general, China is on the track of low carbonization, albeit after 2002, there has been an unfavorable change in China’s economic structure and energy efficiency. However, after the implementation of Energy Saving and Emission Reduction Strategy in 2005, the direction of carbon productivity started to be reversed, embodying the positive effects of implementing energy-saving on promoting economic output per unit of carbon emissions.

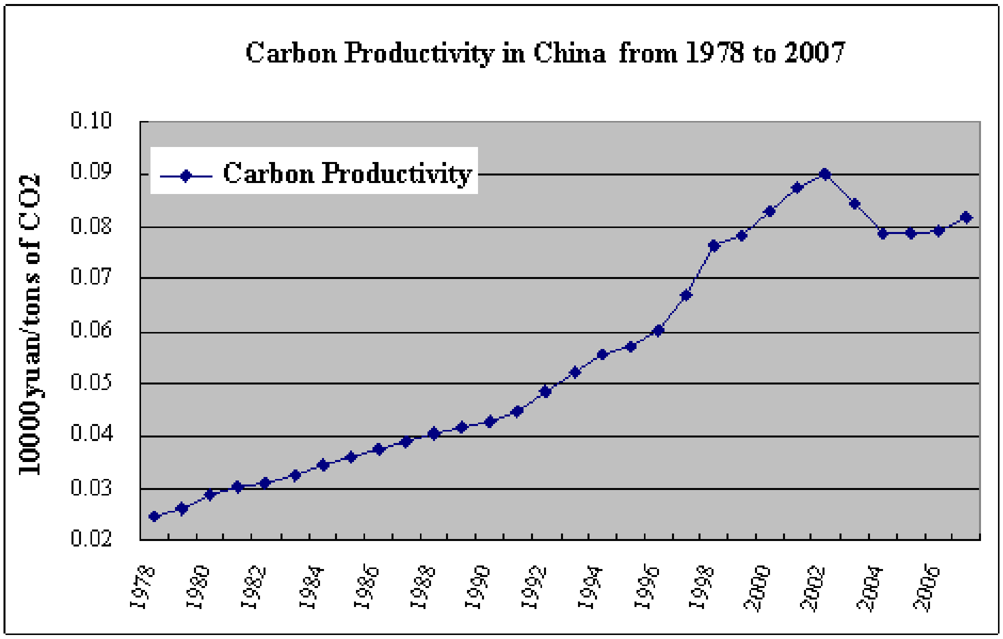


**Figure 1-6：China’ s Carbon Productivity from 1978 to 2007**

Energy reliance varies in different industries because of their characteristics and technology level. Represented by carbon productivity, it is the output variance of 1 ton $CO_2$ emission among industries. Starting from the 1980s, China’s energy intensity has continued to decrease, particularly in the field of industrial sector and the energy intensity has decreased threefold in the past 20-plus years. The next two sectors seeing the biggest decrease are transport and construction. Studies show that during the period from 1980 to 1990, the major reasons for China’s dramatic decrease in energy intensity was the improvement of energy efficiency resulted from technological progress, the restructuring of enterprises and the rising administrative efficiency, as well as the optimization of structure of energy mix. However, after 2003, the decrease in energy intensity has become leveled off. Importantly, it rebounded to some extent. The reason is that a large number of unnecessary constructions and impulsive investment lowered the investment efficiency. In the meantime, the increase in the proportion of heavy industry characterized by high-energy consuming represented by automobile, cement and electrolytic aluminum surpassed the then economic growth, leading to the low energy efficiency use[15].

[15] Shi Bo, Energy consumption, Structural changes and China’s Economic Growth:1952-2005”, ***Contemporary Economic Sciences***, May, Vol.29, No.5

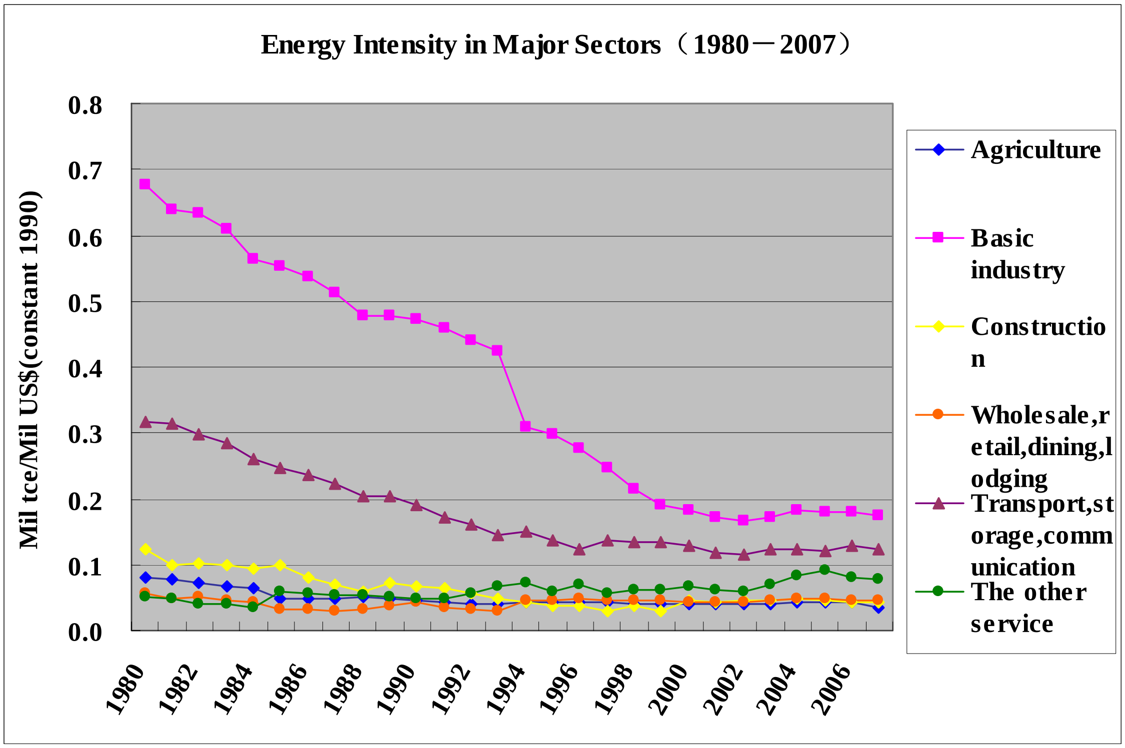


**Figure 1-7：Energy Intensity of major Sectors from 1980 to 2007**

## 2. Comparison of Carbon-Employment Rate in Major Sectors

The following table is a created indicator of Carbon Emission-Employment Rate (or Carbon -Employment Rate, in short, EER), which could uncover the inner relationship between employment and energy consumption of a specific industry.

**Table 2-2：Carbon-Employment Rate in Major Sectors（2005）**

| Industry | Carbon -Employment Rate (tons of $CO_2$ per capita) |
|---|---|
| **Total** | **0.56** |
| **Primary Industry**（Farming, forestry, herding, and fishery, etc） | **28.58** |
| **Secondary Industry** | **0.14** |
| Basic Industry | 0.08 |
| Mining | 0.08 |
| Manufacturing | 0.15 |
| Power, gas, and water production and supply | 0.01 |
| Construction | 12.25 |
| **Tertiary Industry** | **15.67** |

| | |
|---|---|
| Transportation, storage and postal service | 4.02 |
| Wholesale, retail, lodging. and dining | 11.26 |
| Others | 27.77 |

It could be seen from the table that EER of primary and tertiary industry is much higher than secondary industry, which means that incremental carbon emission is lower in primary and tertiary industry corresponding to the same amount of employment increment. Besides, in the tertiary industry, EER of consumer services are mostly higher than that of producer services. For instance, one ton of $CO_2$ emission increment could produce four jobs in transportation industry. While 11.26 jobs could be created in the wholesale, retail, lodging, and dining. And 27.77 jobs would generate in other services.

## 4.3 Conclusion

Overall, since the past decades, China has been on the track of low carbon development characterized by low carbon emission and increasing carbon productivity owing to the technology advancement and decrease of energy intensity.

The green industry and low carbon industry are two different but related areas. The typical characteristics of green industry can be described as being low emission, low pollution, environmental friendly, while the low carbon industry concerns the direct and indirect carbon emissions and productivity.

Plainly enough, each sector plays a different role in our national economic system and the optimization of economic structure is also governed by its inherent pattern of evolution. For this reason, it is unrealistic to expect that the industrial restructuring might be up to par with the level of developed countries within such a short term. China is now in the middle and late stage of industrialization, and China is also in the transitional period from high carbon to low carbon economy. As an important pillar of the national economy, China’s industry is tasked with providing the whole society with material goods. However, such important items as iron, cement, petrochemicals and construction materials are exclusively being produced by high-polluting and energy-dependant industries and constitute the foundation of China’s heavy industries. Taken together, we can conclude that on the one hand, the high carbon industries like steel are a necessary part in the process of upgrading the industrial structure; on the other hand, the low carbonization of high carbon industries is also the inevitable course of realizing the LCE.

Reliable energy supply is the most important prerequisite to the sustainability and stability of economic growth. To minimize its reliance on energy, the most sensible choice is to increase energy efficiency by capitalizing on technological advance. Another important method is to optimize the industrial structure, and bring the high-polluting industries under control. In the meantime, we should vigorously develop technological support services for basic industries and consumption-oriented services so as to promote job generation on the basis of low energy consumption.

# PART II. EMPLOYMENT IMPACT

# 1 Forestry Industry[16]

## 1.1 Climate Change Impacts on Forestry Industry

The ecological environment and forestry development are important contents to deal with climate change and achieve low carbon development. Chinese government has looked on the improvement of ecological environment as the foundation and penetration point of realizing sustainable development and established the strategic position of forestry industry in developing national economy and society.

The impacts of climate change on Chinese forest resource will also affect the development of forestry industry, and consequently will have corresponding effects on forestry employment.

The positive impacts include: (1) in order to mitigate global warming, Chinese government increases the investment in the field of forestry, launches relevant projects of forestry ecological system construction, which have spurred the forestry employment and consequently boosted the shift of labor force and the upgrade of employment structure. (2) New low-carbon industries comes into being, such as carbon sequestration industry, biomass energy forestry, forest products industry, eco-tourism, forest sustainable management, and so on. These industries extend the forestry industrial chain and create some new employment opportunities, which will absorb large amounts of labor forces.

The negative impacts include: (1) climate change and low-carbon development mode restricts the development of wood logging and processing industry and many workers of forest products processing have to be laid off. (2) Forestry employment is also negatively affected by some natural disasters caused by climate change, such as plant diseases, insect pests and extreme weather disasters, and the impacts of climate change on the distribution of forest types and forestry management.

Forestry industry itself is a complete industry chain, including not only the primary industry but also the secondary industry and tertiary industry. Table 1-1 makes a description on the carbon

[16] Team Member include: Prof. Pan Chenguang(CASS), Dr. Ke Shuifa(Beijing Forestry University), Dr. Wang Cuihuai(SFA), Dr. Wang Canfa(CASS), et al.

emission and employment capacity of various forestry industries from the viewpoint of traditional forestry industries and newly emerging forestry industries. Through analysis, we may find that the development of forestry industry is not only favorable for slowing down the process of climate change or adapting to climate change, but also able to create large amount of green employment positions. It is favorable for promoting the transition of low carbon employment to actively develop processing and manufacturing industries, forest by-product industry, eco-tourism and so on.

**Table 2-1: Carbon emission of forestry industry and its capacity of creating job opportunities**

| Variety of Industries | | | Carbon Emission | Contribution to Climate Change | Opportunities of Job Creation |
|---|---|---|---|---|---|
| **Traditional Forestry Industries** | Forest cultivation, plantation and conservation | Forest cultivation | Increasing carbon sink | Positive | Strong |
| | | Forest plantation | Increasing carbon sink | Positive | Strong |
| | | Forest conservation | Increasing carbon sink | Positive | Strong |
| | Forest harvesting and transp. | Forest harvesting | Carbon emission | Negative | Weak |
| | | Forest transportation | Carbon emission | Negative | Weak |
| | Processing and manufacturing of forest product | | Carbon emission | Negative | Medium |
| | Plantation and gathering of non-timber forest product | | Increasing carbon sink | Positive | Strong |
| | Flower industry | | Increasing carbon sink | Positive | Strong |
| | Bamboo industry | | Increasing carbon sink | Positive | Strong |
| **Newly Emerging Forestry Industries** | Forest tourism, forest leisure and forest culture | Forestry tourism industry | Low carbon emission | Neutral | Strong |
| | | Forestry leisure Industry | Low carbon emission | Neutral | Medium |
| | | Forestry culture industry | Low carbon emission | Neutral | Medium |
| | Non-wood product industry | | Low carbon emission | Neutral | Strong |

| | | | | | |
|---|---|---|---|---|---|
| | Forest ecological service | Forest carbon sink | Increasing carbon sink | Positive | Medium |
| | | Forest hydrological service | Increasing carbon sink | Positive | Medium |
| | | Biodiversity protection | Carbon sequestration | Positive | Medium |
| | | Other forest ecological service | Increasing carbon sink | Positive | Medium |
| | Forest bio-industry | Bio-energy resources | Carbon substitution | Positive | Strong |
| | | Bio-material | Carbon substitution | Positive | Strong |
| | | Bio-pharmaceutical industry | Carbon substitution | Positive | Strong |
| | | Green chemicals | Carbon substitution | Positive | Strong |
| | | Green food | Carbon substitution | Positive | Strong |

## 1.2 Methods for forestry industry to promote low carbon development

Forestry has quite positive effects on the execution of Chinese low-carbon development. Carrying out forestry action, such as afforestation, re-afforestation, forest management, wetland protection, and fossil energy substitution, can not only effectively absorb carbon dioxide and mitigate greenhouse effect but also increase jobs (Jia Zhibang, 2008) .

The main methods for forestry industry to promote low carbon development include afforestation and re-afforestation, forest ecosystem management, and forest tour etc.（figure 2-1）

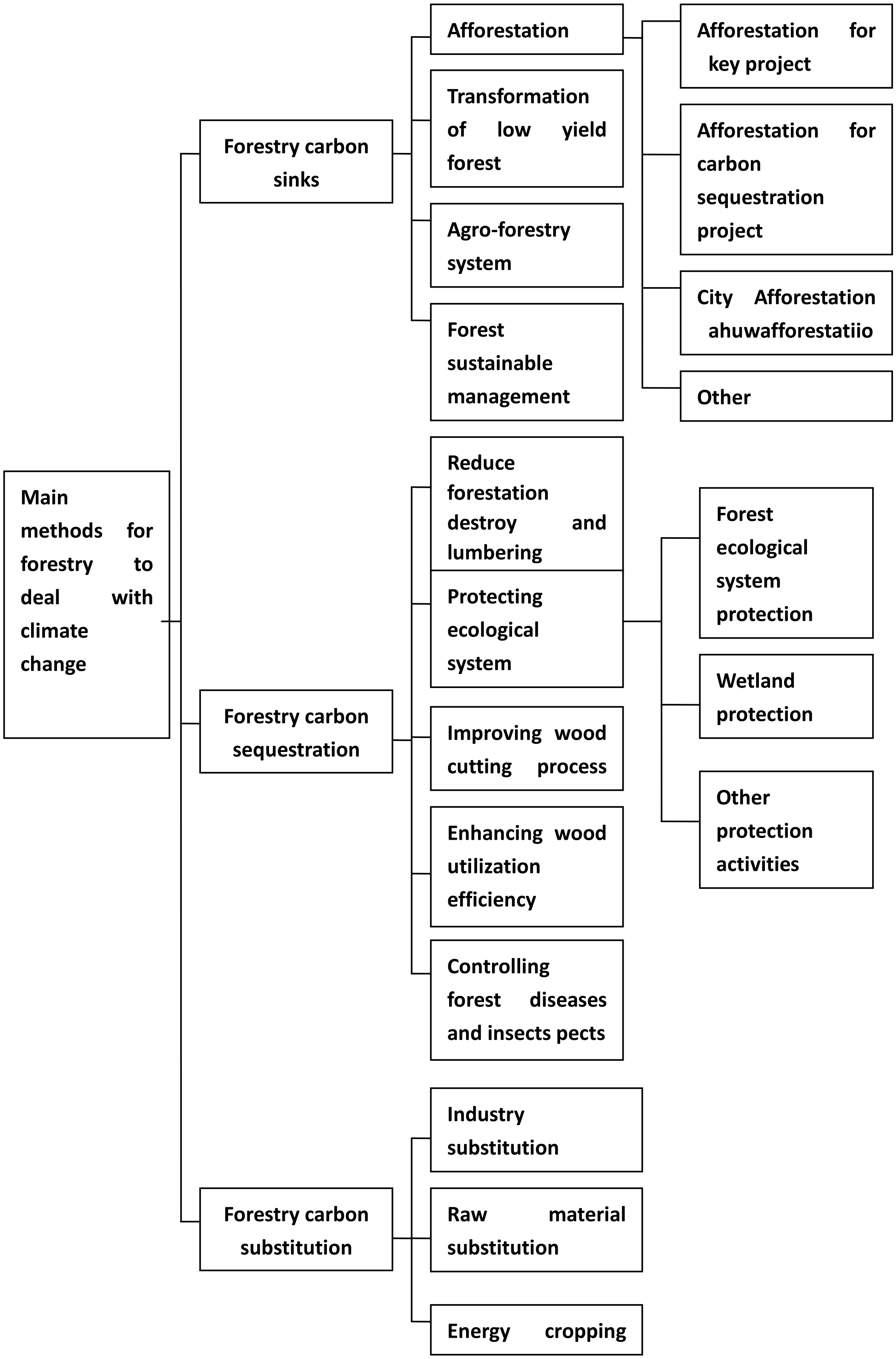


**Figure 2-1: Framework of Forestry and Climate Change**

### 1.2.1 Forestry Carbon Sinks

Carbon Forestry aims to play the full role of forest as carbon sequestration, to lower the carbon dioxide concentration in atmosphere, and to mitigate climate change. As the cost of carbon dioxide absorption and fixation by the measures of plantation and forest protection is much lower than the cost of industrial emission reduction, forestry action becomes one of the most economical and effective measures to reduce greenhouse gas emission.

### 1.2.2 Forestry Carbon Sequestration

Forestry carbon sequestration action is to preserve and maintain present carbon stored in forest ecological system so as to reduce the carbon emission. With the forest sustainable management, a series of carbon management measures are adopted to reduce carbon emission and increase carbon sequestration so as to gain the most profit of carbon sink, including ecological conservation, reducing disforestation, improving woods operation measures, enhancing wood utilization efficiency, and effectively controlling forest disasters (forest fires, plant diseases and insect pests). China has realized the important effect of forest in improving climate change and increasing carbon sinks. China's State Forestry Administration has put the job of carrying out forestry carbon sink into the overall forestry development strategy, and started several afforestation and re-afforestation projects. Although not all afforestation activities can be brought into CDM projects[17], latent international carbon market demand provide a good developing opportunity for Chinese carbon forestry(The distribution of Carbon Sink Projects in China can be seen in the following map 2-2).[18]

[17] Generally speaking, afforestation under CDM refers to the plantation on land which hasn't grown forest for a long period. UNFCCC (2001) the Marrakesh Accord defines afforestation as "the direct human activity of establishing a forest on land that has not been a forest for at least past 50 years by artificially planting trees, their seeds or artificially promoting natural seminationsowing"(UNFCCC, 2001a). Reaffoestation refers to the direct human activity of turning a land which once was a forest but changed into non-forest into forest by transplanting, sowing or artificially promoting natural seminationsowing.

[18] In 2004, Carbon Sink Office of China's State Forestry Administration started the Forestry Carbon Sink pilot program in Guangxi, Inner Mongolia, Yunnan, Sichuan, Shanxi and Liaoning (Li Nujiang 2007), among which CDM projects in Kyoto Protocol is applied in Guangxi and Inner Mongolia.

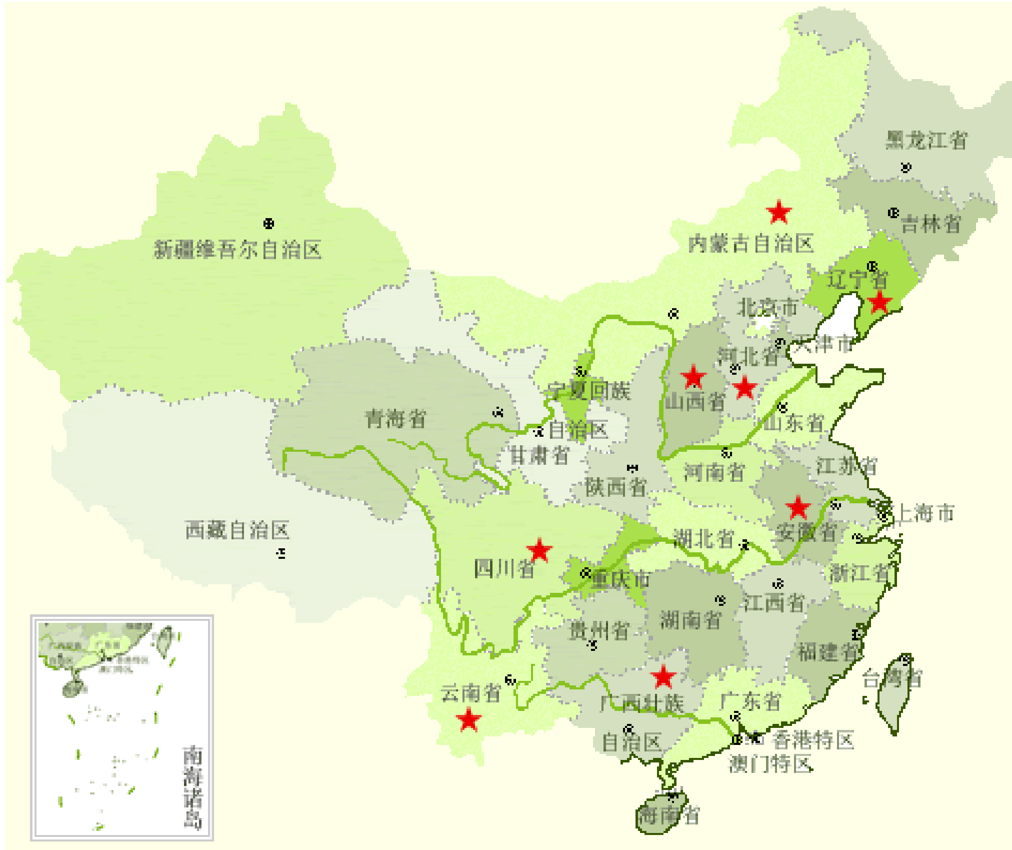


**Figure 2-2: The distribution of Forest Carbon Sink Projects in China**

### 1.2.3. Forestry Carbon Substitution

The action develops the rising low-carbon industry instead of traditional high-carbon forestry industry, develops durable wood products instead of energy-intensive materials, and uses renewable wood fuel (like fuel wood forest) and logging residue. It includes: (1) Industry substitution: in order to reduce carbon emission, such as forest cultivation, maintenance industry, eco-tourism and bio-industry. (2) Energy substitution: namely energy forestry or energy cropping, aims to substitute fossil energy for biomass energy, mainly to make use of barren mountains and wastelands which are suitable to develop forestry and lands unsuitable for cultivating such as sands, saline and alkaline. According to the “Development Plan for National Energy Forestry” promugated by the State Forestry Administration, China will build 667,000 hectares of model base of energy froestry during the period of 11th Five-year-plan; by 2020, its energy forestry will achieve 13340,000 hectares which can provide 6 million tons biodiesel and meet the fuel need of more than 11,000,000 kilowatts of power plants. (3) Raw material substitution: Energy-intensive materials (as iron, cement, aluminium product, plastic, and tile) can be substituted by durable wood products, so as to increase land carbon storage and decrease the greenhouse gas emission produced by burning fossil fuel in the course of energy-intensive material production.

## 1.3 Afforestation and Re-afforestation

### 1.3.1 General Situation of Chinese Forestation

In terms of Tokyo Protocol ratified in 1997, the promised goal of reducing and limiting greenhouse gas emission can be offset by the carbon dioxide absorbed by afforestation, reafforestation and forest management since 1990. Forestry activities have become one of the most economical and effective measures for each country to reduce and limit emission. It is estimated that the greatest potential of carbon sequestration in 2000~2005 is 1.53~2.47 billion tons carbon per year, of which is 28% afforestation, 14% reafforestation, and 7% agro-forestry.

China has been carried out afforestation and re-aforestation activities to promote the improvement of ecological environment and deal with answering the global warming. Since 1990s, China has successively put ten forestry key projects into effect and the plan range has covered 97% counties of the whole country. The planed afforestation and re-aforestation mission has been over 7.34 million hectares. The Sixth National Forest Inventory(1999-2003) concluded that China’s forest coverage is 18.21%. China’s forest area is No. 5 and its forest reserve is No.6 in the world. “The National Climate Change Programme” points out that the cumulative net sequestration of China’s Afforestation is 3.06 billion tons of carbon dioxide, 1.62 billion tons carbon emission reduction from forestry management, 0.43 billion tons by reducing forestry destroy.

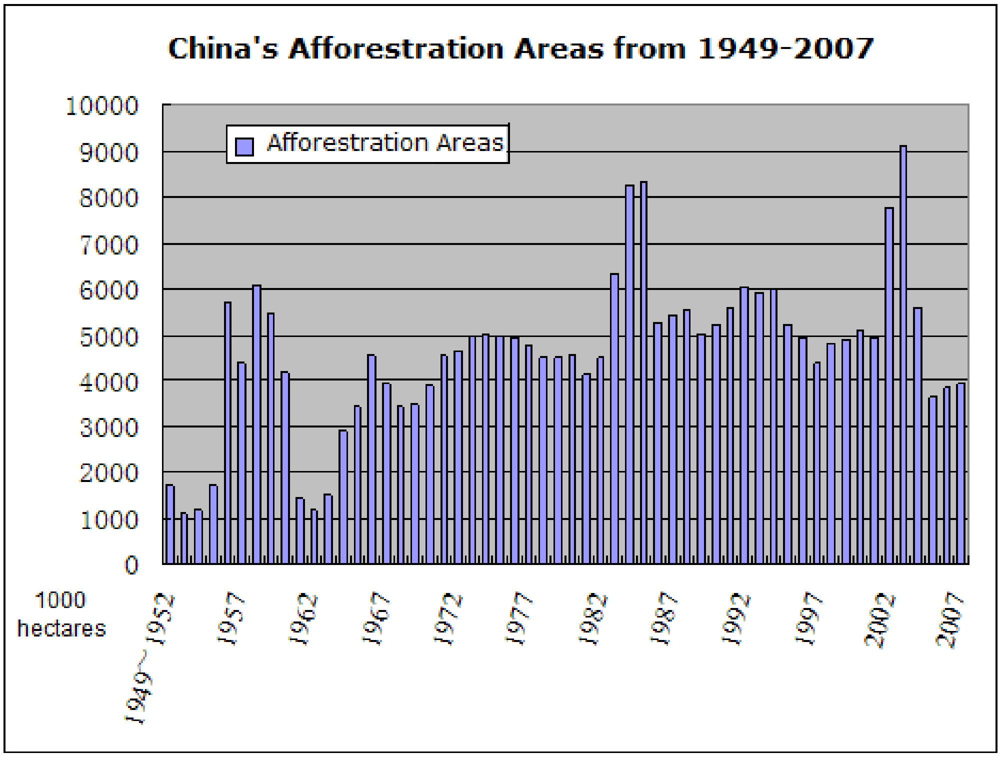


**Figure 2-3 National Afforestation Areas Over the Years**[19]

Forestry is characterized by following features: (1) labor intensive, with great potential to absorb great many workers; (2) green industry, with great capability and contribution for carbon-sink and environment protection and low-carbon economy; (3) seasonal work in planting trees(mainly in spring), and the related employment are mostly temporary; (4) It is connected to a wide range of activities, and therefore is an indirect force in driving employment in related industries besides the forestation business. A typical forestation project includes project planning, on-site clearing-up, land ploughing, seedling preparation, tree-planting and post-plantation administration. The industrial chain of forestration is displayed in Fig. 2-4 as below:

[19] 1. Afforestation area is counted as the survival rate arrives to 40% before 1985 while to 80% hereafter.
2. According to Afforestation Technical Regulations (GB/T 15776-2006), the area of new forest conservation on non-stocked and open forest land has also been counted into the total afforestation area since 2006.

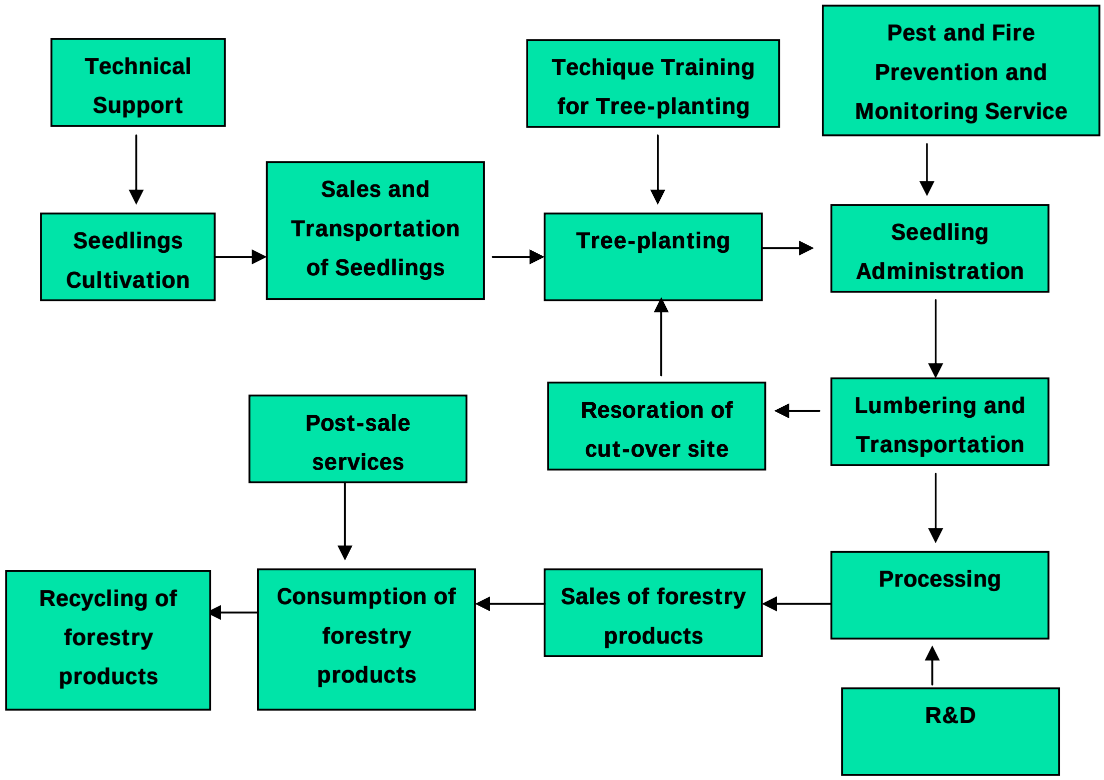


**Figure 2-4 Industrial Chain of Forestration**

### 1.3.2 The direct employment effect of Afforestation activities

In general, large-scale afforestation will affect the other land-use to a certain extent, such as reducing farm employment. As an example， the afforestation areas have completed 2001.05 million hectares from 1999 to 2007， of which 812.62 million hectares farmland to forest. In the result, the amount of farm labor has reduced 24379 million man-days and the amount of farmland to forest labor has increased 11377 million man-days in the project of conversion from cropland to forest. Converting into the standard labor force (accounting jobs based on 300 days of work per person per year), the employment effects of the policy of conversion from cropland to forest was cumulative net reduction of 433,000 jobs (see Table 2-2).

**Table 2-2: impact of China's implementation of the conversion from cropland to forest Project on the employment**

| year | The total afforestation areas | Afforestation of barren hills and wasteland areas | cropland to forest areas | added amount of labor for cropland to forest this year | reduced amount of farming labor this year | net reduced amount of labor this year | reduced number of jobs |
|---|---|---|---|---|---|---|---|
| | Million hm² | Million hm² | Million hm² | Million man-days | Million man-days | Million man-days | （1000） |
| 1999 | 46.7 | 7.01 | 39.69 | 556 | 1191 | 635 | 21.17 |
| 2000 | 88.47 | 45.67 | 42.8 | 599 | 1284 | 685 | 22.83 |
| 2001 | 89.03 | 48.49 | 40.54 | 568 | 1216 | 649 | 21.62 |
| 2002 | 442.36 | 238.38 | 203.98 | 2856 | 6119 | 3264 | 108.79 |
| 2003 | 619.61 | 311.02 | 308.59 | 4320 | 9258 | 4937 | 164.58 |
| 2004 | 321.75 | 239.26 | 82.49 | 1155 | 2475 | 1320 | 43.00 |
| 2005 | 189.83 | 123.1 | 66.73 | 934 | 2002 | 1068 | 35.59 |
| 2006 | 97.7 | 75.85 | 21.85 | 306 | 656 | 350 | 11.65 |
| 2007 | 105.6 | 97.73 | 5.95 | 83 | 179 | 95 | 3.173 |
| Cumulative | 2001.05 | 1186.51 | 812.62 | 11377 | 24379 | 13002 | 433.40 |

Data source: 1999-2007 Statistical Yearbook of China Forestry, State Forestry Administration

In fact, implementation of conversion cropland to forest, in addition to afforestation, has also created many new jobs, such as pre-survey before implementation of the project, engineering planning and design, training of engineering implementation, engineering assessments and monitoring, etc. If we consider a variety of indirect employment effects of afforestation activities, such as forest management and protection, forest tourism, forestry and other sideline, the impact of conversion cropland to forests on employment should be fairly positive. In addition, mainly used fields for afforestation are barren hills and wasteland in China, even conversed lands were mostly lower farming output rate.After 2006, in order to protect food production, conversion cropland to forest areas have significantly reduced, turning to consolidate the preliminary results of conversion cropland to forest by forest management and proctection. In the project implementation process, the central and local governments and the forestry-related functional departments have attached great importance to development of alternative industries and labor force training, and the surplus labor force in most regions after conversion cropland to forests has generally been a good transfer or resettlement, therefore, negative impact on employment of afforestation projects is not significant as a whole.

Assumed ignoring the negative impact of the afforestation and reforestation project on the agricultural employment, the corresponding number of jobs can be measured in accordance with afforestation areas. Based on "shelterbelt afforestation project investment estimate indicators" issued by the State Forestry Administration in January 2009, namely, afforestation (forest clearing +land preparation + saplings planted+ tending, not including the daily management and protection) , the amount of afforestation labor per hectare is about 71-136 man-days, an average of 103.5 man-days, you can measure out the amount of labor for afforestation in China 2005-2008.

**Short-term employment effects of afforestation**

**= labor of per unit afforestation area ×afforestation area of the year**

Calculated to be 2005 ~ 2008 China's afforestation activities in an accumulated increase of the total increased short-term employment of China's afforestation activities from 2005 to 2008 is about 1.733 billion man-days (Table 2-3), if measuring based on 300 man-days / year as a standard job to measure, it can increase total 5.7749 million person's short-term employment. Therefore, the pulling the employment effects of forest actions is considerable

**Table 2-3 labor units accounting for afforestation from 2000 to 2007**

| **year** | The total afforestation area (1000 hectares) | Labor volume (million man-days) |
|---|---|---|
| 2000 | 5105.14 | 52838 |
| 2001 | 4953.04 | 51264 |
| 2002 | 7770.97 | 80430 |
| 2003 | 9118.89 | 94381 |
| 2004 | 5598.08 | 57940 |
| 2005 | 3637.68 | 37650 |
| 2006 | 3838.79 | 39731 |
| 2007 | 3907.71 | 40445 |
| 2008 | 5354.77 | 55421 |
| 2003-2008 | 31455.92 | 325568 |
| 2005-2008 | 16738.95 | 173247 |

According to《"Forestry development" Eleventh Five-Year "and the long-term planning"》 issued by the State Forestry Administration, China's forestry development in the near future, medium-and long-term goals are: the forest coverage rate of 20% or more in 2010; the forest coverage rate reached 23% or more in 2020; forest coverage rate reached and stabilized at 26% or more in 2050. the afforestation areas to be needed to achieve the desired goal can projected, thus the new forest area is the increasing afforestation areas, to facilitate the calculation, assuming that forest conservation rate was 100%. As technological progress and raising the level of forest management, the required amount of labor will be reduced because of increasing labor productivity in the future. Based on the amount of labor per hectare of afforestation activities in China over the years, and assumed rate of labor productivity on average up to 20.14%, then the correction factor of labor is 79.86%. Using the following formula for estimating annual new jobs of afforestation activities in the future(Table 2-4).

**Number of jobs = afforestation labor units (man-days) / (300 man-days / person)**

**Table 2-4: China's forest carbon sink potential and new employment potential**

| **Index** | Forest cover rate | Forests areas | Forests carbon reserve[20] | New afforestation area | amount of new afforestation labor | Added number of standard jobs |
|---|---|---|---|---|---|---|
| **Unit** | % | Million hectares | 100 million tons of carbon | 1000 hectares | million man-days | 10000 person |
| **2005** | 18.20% | 1.75 | 144.3 | - | - | - |
| **2010** | 20% | 1.92 | 158.5 | 1719.28 | 1779.45 | 47.4 |
| **2020** | 23% | 2.21 | 182.3 | 4600.81 | 4761.84 | 126.8 |
| **2050** | 26% | 2.50 | 206.0 | 7482.34 | 7744.22 | 20.62 |
| **2005-2008** | - | - | - | 16738.95 | 173247 | 577 |
| **2009-2020** | - | - | - | 14552.18 | 150616 | 183 |
| **2021-2050** | - | - | - | 28815.3 | 298238 | 794 |

[20] following formula Estimating of forest carbon reserves

Formula 1: forest cover rate= Forest area / land area

Formula 2: The reserves volume of the unit forest area = forest stock / forest area

Formula 3: Forest biomass carbon (C1) = forest reserves × expansion coefficient (1.9) × volume factor (0.5) × carbon ratio (0.5) = 0.475 × forest reserves

Formula 4: Total fores carbon (C2) = tree biomass carbon reserves + the amount of understory vegetation + forest carbon sequestration carbon sequestration = 2.439 × 0.475 × forest reserves

In the input - output table, afforestation activities should belong to "forestry" sub-sector under the "agriculture" sector. Therefore, we can calculate the indirect and induced employment brought about by the afforestation activities to the whole economy according to various employment coefficients of the agricultural sector (Table 2-5) .

**Table 2-5: Indirect and induced employment from newly afforestation activities**

| Index | Indirect employment | Induced employment |
|---|---|---|
| **Unit** | Million person s | Million persons |
| **2005-2008** | 3.003 | 5.413 |
| **2009-2020** | 0.952 | 1.717 |
| **2021-2050** | 4.132 | 7.449 |

## 1.4 Forest Ecological System Management

Apart from the temporary job opportunities offered by the seasonal forestation programs, post-plantation administration may also create some long term jobs. We may calculate the newly created long term jobs by using data on newly increased areas of forestation in 2010, 2020 and 2050, and by referring to the standard quota of workload in forest administration published by the State Forestry Administration in its “Evaluation Guidelines for Investment in Shelter Belts Program”[21], where one employee is directed to administer 150 hectare of land per year.

**Table 2-6: Newly Created Long-term Jobs( Forest Sustainable Management)**

| Year | Newly afforested area (10,000 hectare) | Newly created long-term jobs (1000 persons) |
|---|---|---|
| **2005-2008** | 16738.95 | 89.27~111.59 |
| **2009-2020** | 14552.18 | 77.61~97.01 |
| **2021-2050** | 28815.3 | 153.68~192.10 |

Note: The numbers of Long-term jobs give a forecast range. The maxes are based on the forecast value of the existant labor productivity and the mins are base on the forecast value of improved labor productivity and technique level.

[21] Promulgated by the State Forestry Administration, published by China Forestry Publishing House in 2009

According to the “Evaluation Guidelines for Investment in Shelter Belts Program” published by the State Forestry Administration, the cost standard of shelter management and protection is 48 yuan per hectare. Forestry management and protection belongs to the department of water conservancy, environment and public facilities management industry in the input-output table in which industry labor coefficient, indirect employment coefficient and induced employment coefficient are 0.0944, 0.0126 and 0.018 respectively. Then we could calculate the indirect and induced employment effect of the forestry management and protection investment shown in table 2-7.

**Table 2-7: the Indirect and Induced Employment Effect of Newly Created Long-term Jobs ( Forest Sustainable management)**

| Year | Indirect employment(1000 persons) | Induced employment (1000 persons) |
|---|---|---|
| **2005-2008** | 11.88～14.85 | 17.02～21.28 |
| **2009-2020** | 10.33～12.91 | 14.80～18.50 |
| **2021-2050** | 20.45～25.56 | 29.31～36.63 |

Note: The numbers of Long-term jobs give a forecast range. The maxes are based on the forecast value of the existing labor productivity and the minimum estimates are base on the forecast value of improved labor productivity and technique level.

## 1.5 Forest Tourism

### 1.5.1 Status quo and its potential of forest tourism and direct employment

As a crucial part of low-carbon industry, forest tourism helps the transition of the traditional forestry industry to a modern one. With people’s improving living standard, countries worldwide are paying closer attention to ecotourism, which is dominated by forest tourism. Forest tourism has become the most thriving industry with the greatest potential in our tourism industry as a whole. It is called vividly as “the no-smoke emerging industry in the 21st century”.

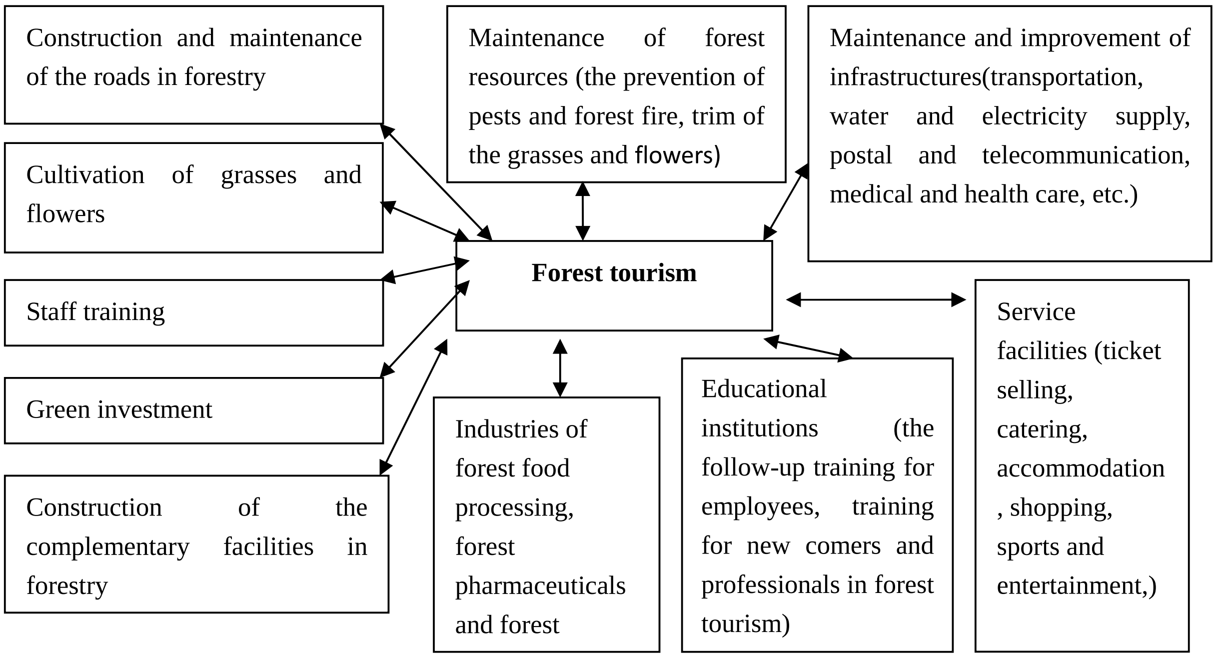


**Fig.2-5 The analysis of Industry chain in forest tourism**

Because forest tourism is a highly integrated industry, it has high industry's related degree, and strong radiation and spillover effects on the national economy (Fig.2-5). Forest tourism not only enjoys direct connection with industries such as tourism, commerce, service, transportation and forest cultivation, but also has indirectly links with industries such as fitness and recreation, urban construction, environmental protection, water conservancy, cultural heritage, religion and so on. The cooperation development of this industry chain as a whole is able to create new jobs and sectors in various industries, particularly in those emerging ones, such as forest health care, forest industry investment, forest tourism personnel training and leisure and cultural industries etc.

China enjoys the advantages and potential in developing forest tourism. Currently there are more than 4200 state-owned forest farms and over 150,000 collective-owned forest farms in China. Adding the large-scale state-owned forest areas, China boasts rich resources that can be developed into tourism attractions. As the construction of shelter forest projects in northeast, north and northwest as well as in coastal areas is advancing and the mountainous regions and deserts are developing, many new tourism attractions of forests are created. Forest tourism, in broad sense, includes activities in forest parks, wildlife conservation areas and hunting grounds and other tourism actives. It has great positive impacts on job creations directly. According to statistics, in 2008, the number of employees working in management and service in the forest parks across the country reached 134,000, up from 36,000 in 1998. According to “China’s Forestry Yearbook”, during the period of the “10th Five-Year” Plan, forest parks have offered over 1.6million jobs in total. Since 1990s, the State Forestry Administration has invested a special fund of more than 1.1billion RMB in the construction of forest parks based on the principle of “striking a balance among construction, operation and profits”, providing support to the rapid development of forest tourism. (Fig. 2-6)

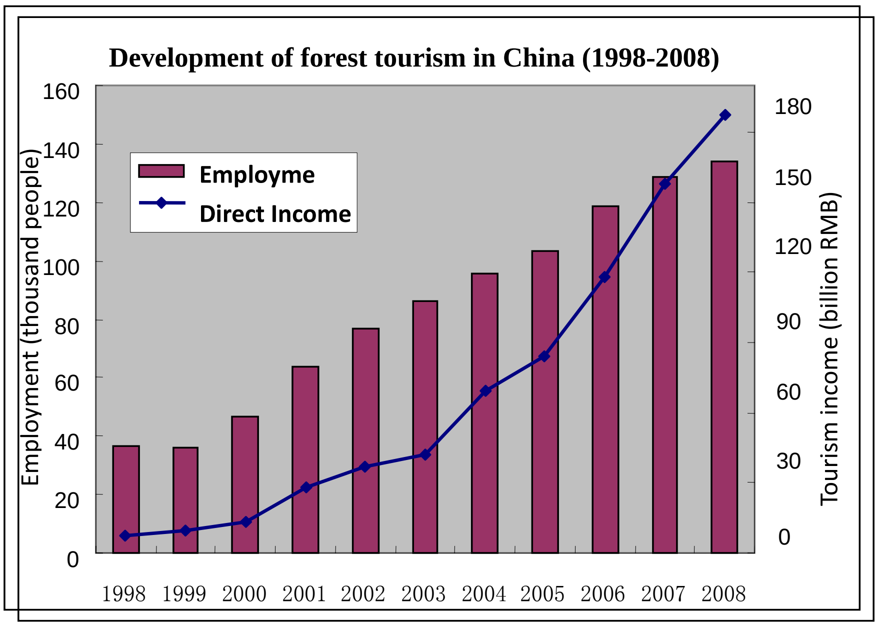


**Fig.2-6 Historical development and the outlook of forest parks tourism**

Source: statistics from China’s Forestry Yearbook

The output value of China’s forest tourism is accelerating over the recent years. However, the industry is still less competitive in scale, profits and contribution to GDP compared to other countries. Some researches indicate that in America, more than 92% of the forest land are open to the public for outdoor recreation. Each year, forest tourism attract more than 300million person-time, with an annual consumption of up to 300billion USD. In Germany, a slogan called “open forests to the public” is made. The tourism income in forest parks across Germany reach 8billion USD, accounting for 67% of the total domestic tourism income; Latin America started to develop forest tourism relatively early in the world. Now the income of forest tourism in this region accounts for over 90% of the total tourism income. In contrary, the out-put value of China's forest tourism in 2007 was only 87.639billion RMB, accounting for only 0.8% of the total tourism income. According to the prediction of the experts, by the end of 2020, China's forest tourism will reach a double digits growth, and the number of Chinese forest tourists will account for more than half of the world total number. Based on this prediction, by 2020, the number of Chinese forest tourists is expected to reach 400million person-time.

According to the historical data from "China's Forestry Yearbook", China's annual forest tourism revenue grows very fast; the average annual growth rate is about 40.8%. Within this time period, the growth rate of tourism revenue fluctuates greatly. Based on this fact, we will assume there are 3 development scenarios of China's forest tourism industry. The high development scenario assumes the current tourism revenue growth rate will continue till 2015, after that, the growth rate will decline to 20% per year. The second scenario assumes the average annual growth rate of forest tourism will maintained at about 20% from 2009 to 2020. The low scenario assumes that the rate is 20% from 2009 to 2015 and drop to 10% after 2015. The Forest tourism's contribution to employment growth can be shown by the elasticity of employment income. Given the availability of the evidence, we define the forest tourism as tourism in forest parks in a narrow sense. With the help of statistics on the forest parks which is made by the Forestry Administration, we are able to calculate that between 1998 and 2008, the elasticity of employment income in forest parks tourism is around 0.40. In other words, if income in forest parks grows by 1%, the number of directly-created jobs in forest parks will increase by 0.4% accordingly. From 2005 to 2020, the direct employment created by China's forest tourism industry under these three scenarios can be shown in the table 2-8 below.

**Table 2-8: The prediction of China's direct forest tourism employment (2005～2020)**
**（Unit：10,000 person）**

| Year | Low Scenario | Middle Scenario | High Scenario |
|---|---|---|---|
| 2005 | 10.3 | 10.3 | 10.3 |
| 2006 | 10.9 | 10.9 | 10.9 |
| 2007 | 12.0 | 12.0 | 12.0 |
| 2008 | 13.4 | 13.4 | 13.4 |

| | | | |
|---|---|---|---|
| 2009 | 15.5 | 14.6 | 14.6 |
| 2010 | 17.8 | 15.7 | 15.7 |
| 2011-2015 | 136.2 | 97.9 | 97.9 |
| 2015-2020 | 242.4 | 140.6 | 126.3 |
| Accumulated Jobs Created | 458.6 | 315.4 | 301.1 |

Source: statistics from China's Forestry Yearbook and the National Statistics Bureau

### 1.5.2 Direct employment effects of tourism industries

It is difficult to precisely calculate tourism's effects on boosting jobs because: first, tourism wasn't included in the "2005 Input-output Table" issued by National Statistics Bureau; second, tourism is interconnected with almost all the industries in the national economy, feeding the needs of both the tourists and the local residents. In our research, we adopt the coefficient-free approach proposed by Li Jiangfan and Yi Shaohua. According to "China's Statistic Yearbook 2006", we are able to calculate the proportion of the income of tourism-related industries in the total output value. Based on that, we can calculate the employment multiplier of the tourism-related industries and the direct contribution the tourism makes to the whole society and the tertiary industry, so that we can scientifically analyze tourism's effects on social economy and employment. The approach is shown as follows:

According to the current statistical pattern, tourism-related industries covered in the income statistics can be put into the following six categories: transportation and warehousing industry; postal service, retail and wholesale trading industry; catering and accommodation industry; residents' service; culture, sports, entertainment and other service industries. According to the statistics on tourism, the income of those categories is calculated separately. The calculation based on the data in literature is: transportation 29.8%，accommodation 17.3%，catering 18.4%，shopping 18.2%，entertainment 1.4%，sightseeing 9.5%，others 5.5%. Hence we are able to know the income effects and the direct employment that tourism brings to related industries. (Table 2-9)

**Table 2-9: Income contribution of different sectors in tourism and their direct employment effects in 2005**

| Industries | Income contribution tourism makes to related industries ％ | Contribution of added value（100million RMB） | Direct employment effects（1000people） |
|---|---|---|---|
| Transportation and warehousing | 29.8% | 2339.9 | 533.50 |
| Postal service | 1.4% | 69.1 | 58.67 |
| Retail and wholesale trading | 18.2% | 1484.5 | 417.15 |
| catering and accommodation | 17.3%＋18.4% | 2421.3 | 392.25 |
| Residents' service and others | 5.5% | 1163.6 | 95.42 |
| Culture, sports and entertainment | 9.5% | 213.42 | 95.61 |
| **Total** | **100％** | **7685.7** | **1592.59** |

### 1.5.3 Indirect and induced employment effect of forest tourism

Give the current statistics data, we categorize the income of tourism in the related tertiary industries in 2005, and then we analysis the direct, indirect and induced job opportunities, according to the labor coefficient and employment effects of various industries. The results are shown in detail in the table below (Table 2-10)

**Table 2-10 Indirect and induced employment effects brought by tourism-related industries in 2005(unit: 1000people)**

| Industries | Indirect employment | Induced employment |
|---|---|---|
| transportation and warehousing | 304187 | 2606649 |
| postal service | 31579 | 28677 |
| Wholesale and retail | 124698 | 455742 |
| accommodation and catering | 244551 | 1460044 |
| resident service and others | 50035 | 2193386 |
| culture, sport and entertainment | 53995 | 156010 |

| | | |
|---|---|---|
| Total | 809045.1 | 6900507 |

Source: calculated by the author

As shown from the result, the total income of tourism in 2005 created around 1.59million direct job opportunities in related tertiary industries. Moreover, with the expansion of the industry chain, these related tertiary industries can create up to 1.83 million job opportunities. According to above-mentioned empirical data, we may infer one direct job opportunity in tourism industries will be create 1.15 other job opportunities in economic system.

If we assume the structure of forest tourism industry is the same as the whole tourism industry, we may derive the indirect and induced employment effect in the second scenario shown as in table 2-11.

**Table 2-11 Indirect and induced employment effects of forest tourism (2005 ～2020 ) (unit: 10000 people)**

| Year | Direct Employment | Indirect Employment | Induced Employment |
|---|---|---|---|
| 2005 | 10.3 | 4.3 | 7.5 |
| 2006 | 10.9 | 4.6 | 7.9 |
| 2007 | 12.0 | 5.0 | 8.7 |
| 2008 | 13.4 | 5.6 | 9.7 |
| 2009 | 14.6 | 6.1 | 10.6 |
| 2010 | 15.7 | 6.6 | 11.4 |
| 2011-2015 | 97.9 | 41.1 | 71.2 |
| 2015-2020 | 140.6 | 59.1 | 102.2 |
| Total | 315.4 | 132.5 | 229.3 |

Note: The annual total number of direct employment in forest tourism based on Forest Park.

## 1.6 Conclusion and Suggestions

### 1.6.1 Conclusion

Forestry has made great positive contribution for mitigating global climate change. In order to mitigate and adapt to global climate change, forestry mainly adopts three channels, including carbon sinks, carbon reserve and carbon substitution, and series of action. According the research, we can see that a series of actives of forestry dealing with climate change, such as afforestation, forest management and development of forest tourism, can create a large number of green jobs. It has an important strategic significance for the response to global climate change and to ease the employment problem in the context of financial crisis.

The research results show that, from 2005 to 2008 and form 2009 to 2020, the total number of short-term standard direct employment (based on 300 days of work per person per year) created by afforestation are approximately 577 and 183 million respectively; the number of new forest resources management jobs are 11.16 and 9.7 million respectively; the number of direct employment created by forest tourism industry are 357.08 and 1751.46 million respectively (Table 1-12).

**Table 2-11:The employment effects of forestry actions**

| **Employment effect** | | **Direct Effect (10,000 people)** | | **Indirect & Induced Effect (10,000 people)** | |
|---|---|---|---|---|---|
| year | | 2005-2008 | 2009-2020 | 2005-2008 | 2009-2020 |
| **Forestry** | Afforestation & reforestation | 577 | 183 | 841.6 | 266.9 |
| | Sustainable forest management | 8.93～11.16 | 7.76～9.70 | 2.89～3.61 | 2.51～3.14 |
| | Forest tourism | 46.6 | 268.8 | 53.3 | 308.3 |

### 1.6.2 Policy suggestions

In order to better promote the development of forestry and create more green jobs, this study proposes the following policy suggestions:

(1) **Strongly encourage and support forestry development, continuing to carry out afforestation activities in order to create more job opportunities in forestry**. It still exits larger

room for development in current forestry, so governments can introduce relevant incentives and supporting policies, and vigorously accelerate the development of forestry in China, then more environment-friendly green job opportunities can created. On the one hand, it will make ongoing contributions to adapt to and mitigate global warming, on the other hand, help to alleviate the employment pressure in China and the world.

(2) **Better coordinating and handling the relationship between government regulation and market allocation.** The implementation of classification management, innovation of forestry investment and financing markets and the introduction of social capital promote the great development of forestry. For example, in carbon sink forestry development, in addition to the Governments input public financial to carry out afforestation, they should actively establish and improve the forestry carbon sink market, optimizing the carbon emissions trading system, and make full use of the market leverage to realize the potential value of carbon sink markets, and vigorously promote the development of carbon sinks in forestry and employment of carbon sinks fields.

(3) **Make full use of forest tourism to press ahead low-carbon green employment.** Forest tourism has a strong correlation with many service industries and ability to create direct or indirect job opportunities, and tertiary industry also has a low-carbon high-yield characteristics. Therefore, the Governments can integrate forest tourism planning, increase investment and construction efforts, and vigorously encourage the development of forest tourism and related industries, such as forest tourism planning advisory services; exhibition of forest tourism, special characteristics of forest tourism, etc., to promote Green jobs.

(4) **Cultivate and enhance forestry workers' quality of decent work, to encourage more people to participate in forestry.** Through guidance of decent sense, public propaganda, training and education, to establish a "forest green jobs is glorious" career concept, and constantly improve and perfect the social security system of forestry work, and forestry skills training system, employment service system, enhance forestry workers' decent sense and decent ability.

# 2 Power Industry[22]

## 2.1 Background

### 2.1.1 Status Quo of the Development of China's Power industry

As China is now in the process of rapid industrialization and urbanization, it is eager to have sustainable and reliable energy supplies. Compared with other countries around the world, the coal consumption in China's development takes up to 70%, significantly higher than the percentage of other countries. During the period from 2002 to 2008, the percentage of China's coal power generation to the total power generation takes up to more than 80% (see table 2-13). This situation makes it is difficult to reduce the carbon emission level within ht power sector for China.

**Table 2-13: Statistics on the Proportion of Total Power Output from 2002 to 2008**

| Year | Hydropower | | | Thermal Power | | | Nuclear Power | | |
|---|---|---|---|---|---|---|---|---|---|
| | Installed Capacity (MW) | Growth Rate (%) | Percentage in the Total (%) | Installed Capacity (MW) | Growth Rate (%) | Percentage in the Total (%) | Installed Capacity (MW) | Growth Rate (%) | Percentage the Total Output (%) |
| 2002 | 86070 | 3.70 | 24.14 | 265550 | 4.95 | 74.47 | 4470 | 112.86 | 1.25 |
| 2003 | 94900 | 10.25 | 24.24 | 289770 | 9.12 | 74.03 | 6190 | 38.48 | 1.58 |
| 2004 | 105240 | 10.90 | 23.79 | 329480 | 13.70 | 74.48 | 6840 | 10.50 | 1.55 |
| 2005 | 117390 | 11.54 | 22.70 | 391380 | 18.78 | 75.67 | 6850 | 0.15 | 1.35 |
| 2006 | 128570 | 9.52 | 20.67 | 484050 | 23.68 | 77.82 | 6850 | 0 | 1.10 |
| 2007 | 145260 | 11.49 | 20.36 | 554420 | 14.59 | 77.73 | 8850 | 29.23 | 1.24 |
| 2008 | 171520 | 15.68 | 21.64 | 601320 | 8.15 | 75.87 | 9100 | 2.82 | 1.30 |

Source: data based on China Electricity Yearbook and relevant reports on China Power industry Association

China's future power demand is great, taking full account of the development of coal, hydroelectric and nuclear power, during 2010 and 2020 there are still large gaps of the power supply (Figure 2-7), so in order to optimize the energy structure, speeding up renewable energy electricity to make up "the power gap" and promoting low-carbon development is the inevitable choice.

[22] Team member include: Dr. Anhua Zhang (Energy Research Center of National Financing University), Renle Cao (Huadian Power Group of China); Jianjun Wu (PhD Candidate of Northern China Electricity University)，Qiao WANG(Huadian Power Group of China), etc.

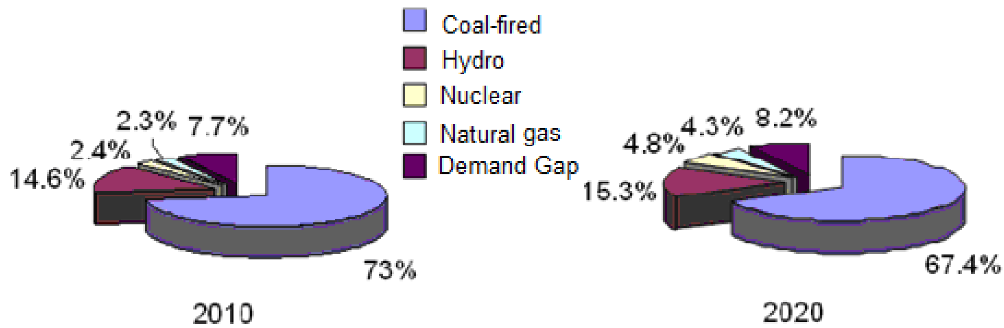


**Figure 2-7: Prediction of China's Future Power Development**

Source: China Electric Power Research Institute

The dominant role of coal in China's power generation dictates that China power industry should play a very key role in China's environmental protection, emission reduction as well as climate change mitigation. China is so far the largest $SO_2$ emitter and the $SO_2$ emission associated with thermal power generation takes up 50% or so of its total emission, with total volume reaching 12 million tons a year. China is also one of the largest CO2 emitters in the world with the total annual emission level associated with thermal power generation reaching 2.8 billion tons. In any sense, reducing emissions of power generation industries under control could significantly minimize the impact of acid rain, improve the environment quality as well as mitigate the speed of climate change.

### 2.1.2 Policies and Measures on Low Carbon Development in Power Industry

In recent years, the power industry has been gradually building norms, standards and management system in the resource-conserving industry, putting the resource-conserving as a key task in its planning, construction, production and management, combining with the effectiveness goal, increased the fundamental management and equipment management, and actively carried out energy-conserving and emission reduction:

**1. Policies and Measures on Energy Saving and Emission Reduction**

(1) **Energy-conserving technologies:** Over the years, the power industry has been increasing the technical innovation, actively promoting new energy-conserving technologies, new materials and new processes, and actively researching energy-conserving technology and applying it; actively supporting and encouraging co-generation thermal power, as well as high efficient generation technologies; constantly improving the power grid structure and HVDC (High Voltage Direct Current) technology to advanced level in the world; constantly pushing forward the large cross-regional networking and implementating the operation efficiency of the electric grid.

（2）**Close down small coal-fired power units, improve energy efficiency:** to develop high efficiency thermal power units of great capacity. By the end of 2008, 300 MW units have accounted for more than 60% of the total installed capacity of large unit

（3） **Energy- conservation in Power Grid Dispatching:** in August 2007, the State Council issued the "energy-conserving Measures in Power Grid Dispatching (for trial implementation)", power generating enterprises should take precedence of wind energy, solar energy, ocean energy and other clean energy for power grid dispatching in accordance with energy- conservation, environmental protection and economic principles.

（4） **Control sulfur dioxide emission**: to accelerate the construction of coal-fired power plants desulphurization installation in 2006, which helped deepen the sulfur dioxide control work and bring rewarding results. By the end of 2008, the total flue gas desulphurization installation volume nationwide has exceeded 379 GW, accounting for 66% of the total capacity of coal-fired power. Now, 85% of national sulfur dioxide emission of power & heat industries is up to the standard.

（5） **Emission trading**: in December 2005, emission trading mentioned firstly in a formal document. In June 2007, the State Council appealed to the regulation on emission trading of sulfur dioxide in *Comprehensive Working Plan for Energy Saving and Emission Reduction*. Since 2008, several Emission Trading Houses were established in Beijing, Shanghai, Tianjin, Changsha, etc.

（6） **Power generation rights trading**: Power generation rights trading aims to promote energy saving and emission reduction by replacing generation of high-efficient larger power units for low-efficient small coal-fired power units. In 2007, 23 provinces carried out the generation rights trading, summing up to 54 billion kWh of power generation.

### 2. Power Generation with Low Carbon Energy Resources

In January 2006, China promulgated *Law on Renewable Energies* and enlisted the sector as a priority for the country's energy development initiatives. In November 2007, with the public appearance of *Mid/Long Term Planning for Renewable Energy*, the Chinese government outlined the principles, development objectives and supporting measures for the industry. And, in recent years, as the boost of *Law on Renewable Energies* and its other correspondent policies began to show, China's renewable energy power generation has landed on the fast lane of development. From 2005 to 2007, installed capacity of renewable energy in power generation industry grew by 36.31 GW, a 30.6% increase, while the installed capacity of hydropower, wind and biomass increased by 26.3%, 444% and 429%, respectively. In the same period, China's power generation capacity of renewable energy increased by 82.2 billion kWh, with the share of hydropower, wind and biomass jumping by 18.9%, 268% and 363%, respectively. The fast development of renewable energy will take a blooming of employment in this sector.

**Hydropower:** In 2008, China's installed capacity of hydropower increased by 20.1 million kW. By the end of that year, the overall installed capacity of hydropower had reached 171 GW, contributing to 21.64% of the country's total power capacity. With the installed capacity of hydropower in rural areas exceeding 50 GW, the annual power generation capacity in China's countryside reached over 150 billion kWh at the end of last year, according to the latest statistics published by Ministry of Water Resources. Home to nearly 50,000 small scaled hydropower stations, China now depends on the small hydro power to support 1/4 of its power hungry population living in 1/3 of its counties that scattered over half of its territory.

**Wind Power**: Since *Law on Renewable Energy* was launched in 2006, China has made remarkable inroads in its wind power sector. In 2008, the overall installed capacity of wind power reached 12.21 GW, with an overall grid-connected capacity of 8.94 GW, and another 10 GW under construction. By 2010, the installed capacity of wind power will have topped 20 GW, making China one of the largest market in the industry. And by 2020, China's installed capacity of wind power is expected to reach 100 GW.

**Nuclear Power:** In March 2006, China passed *Mid/Long Term Planning for the Development of Nuclear Power*. In November, 2007, the State Council ratified the *Special State Planning on Nuclear Power Development*, originally submitted by NDRC. These incidents earmarked that nuclear power industry has entered a new stage in China. At present, 11 nuclear power units are in operation in China, with an overall installed capacity of 9.1 GW, and another 22.9 GW under construction. With three nuclear power plants—Qinshan plant in Zhejiang, Da Yawan plant in Guangdong, and Tianwan plant in Jiangsu—in place, China's overall installed capacity in nuclear power generation is expected to hit 58GW to 60 GW by 2020.

**Solar Energy:** After years of development, Solar-backed power generation industry in China has achieved economy of scale, with ever maturing technologies. By the end of 2008, the installed capacity of photovoltaic system in China had accumulated to 200,000 kW, with over 50 makers of solar batteries in the industry. In all those manufacturers contribute to over 3.5 GW in terms of production capacity, and yields batteries equivalent of 2 GW of electricity annually. With a complete industrial chain ranging from raw material sourcing to the construction of photovoltaic system initially put in place, China's accumulated installed capacity of photovoltaic power is expect to hit 600 MW by 2010.

**Biomass:** China's biomass reserves total 1.5 billion tons of standard coals in theory. Following the eleventh five-year plan's development outline to increase the overall installed capacity of biomass-back power generation to 5.5 GW, the *Mid-/Long-term Development Planning for Renewable Energies* has confirmed that by 2020 the installed capacity of biomass-backed power generation will hit 30 GW. Although by the end of 2008, the overall installed capacity of the industry had hit 3.15 GW, we still need to acknowledge that the development of biomass technology in power generation is in a rudimentary stage.

**3. Carbon Capture and Storage Technology**

Carbon capture technologies are aimed at reducing the emission of power plant by capturing and restoring$CO_2$ emitted in the process of power generation.

On August 31st, 2007, China Huaneng Group signed with Beijing municipal government on *Framework Agreement on Deepening Researches in Carbon Capture and Storage and Maintaining Energy Cooperation*, by which Huaneng Group was to work in concerted efforts with Commonwealth Scientific and Industrial Research Organization of Australia to develop China's first demonstrative project on carbon capture with an annual capacity of 3,000 tons of carbon in Huaneng's thermal power plant in Beijing. The project was to be put into operation prior to the 2008 Beijing Olympics. Actually completed on July 16th, 2008, the project has been in operation for months, and has successfully captured thousands of tons of $CO_2$ with purity of 99.99%. Thanks to its immense social and economic benefits, plans for a second project with annual capture capacity of 60,000 tons of $CO_2$ are now underway.

### 2.1.3 The Impact of Low Carbon Development on Power Sector

When the power industry continues to strengthen environmental protection and actively responds to climate changes, the significant impact on employment arises from the closure of small coal-fired power plants, control of sulfur dioxide emissions and development of power generation with renewable energy. Meanwhile, the strategy for energy saving and emission reduction, the development of cleanness production technology, the implementation of emissions trading and carbon capture technology have some direct and indirect impacts on the employment. Because the strategy for energy saving and emission reduction is applied only in the enterprises internally, There are a small number of employees working for the development of cleanness production technology, the implementation of emissions trading and carbon capture technology, it is hard to determine the exact number of personnel needed. So the related impacts will not be discussed later. Herein, only the influence of the closure of small coal-fired power plants and control of sulfur dioxide emissions on the employment are analyzed in the research.

According to the figure 2-8 below, the implementation of low carbon strategy in response to climate change in the power generation industry will significantly impact the available job positions in two ways. On the one hand, the closing down of technologically incompetent and low efficient coal-fired power units which always have small capacity per unit will inevitably reduce the available jobs. On the other hand, building large capacity power units and reducing the small capacity power units will create new job opportunities. Furthermore, some environment-friendly energy sources characterized by zero emission such as wind power electricity, solar power electricity, hydroelectricity, biomass electricity, geothermal electricity as well as tidal energy electricity etc should be developed without delay due to the considerable potential. All of these zero emission energies have a direct or indirect bearing on the job opportunities.

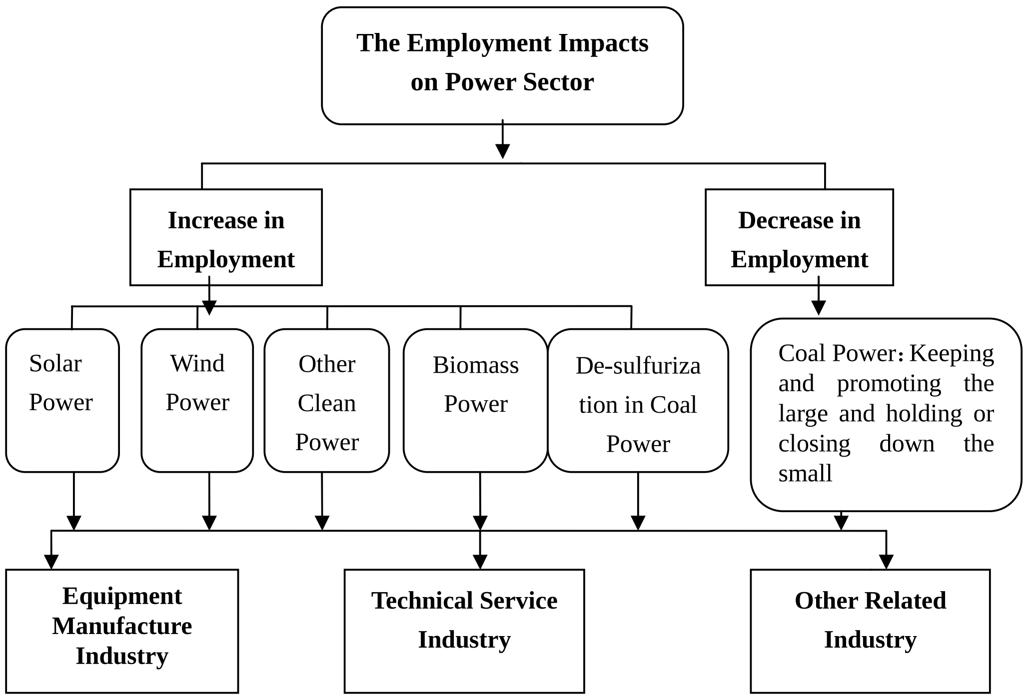


**Figure 2-8 The Impact of Low Carbon Development on Power Sector**

## 2.2 Coal-fired Power Industry

Negative impact on employment of coal-fired power comes mainly from closing down small coal-fired power plants. Positive impact on employment (increase of employment) comes mainly from the installment of de-sulfurization equipments[23].

### 2.2.1 Closing down Small Coal-fired Power Plants and Its Impact of on Jobs

According to National Energy Administration (NEA) data, the closed-down small coal-fired

[23] Based on interviews, it's said that the de-sulfurization equipments take much energy for running and special for control of $SO_2$ but not contribute much to $CO_2$ reduction. Here we still take it as a low carbon incentive sector.

power units in 2008 is 16.69 GW, accounting for 13.9% of total small coal-fired power unit capacity. From now on, more and more small units will be out of use. For old small units with high coal consumption, the closing down capacity will be increased to 125 MW or 200 MW. By the end of 2008, the total capacity of China is 792 GW, high-energy-consumption small units accounting for 100 GW. Small units of 13 GW, 10 GW and 8 GW will be closed down in the coming three years respectively, and large-scale, high efficient, clean coal-fired units of 50 million kW will be built at the same time. Therefore, the employment effect of ‘Closing down the small and building up the large’ policy will have both negative and positive effect.

**1. Jobs Lost Number of Closed Small Coal-Fired Power Plants**

The number of small Chinese coal-fired power plants closed or to be closed from 2003 to 2020 is shown below:

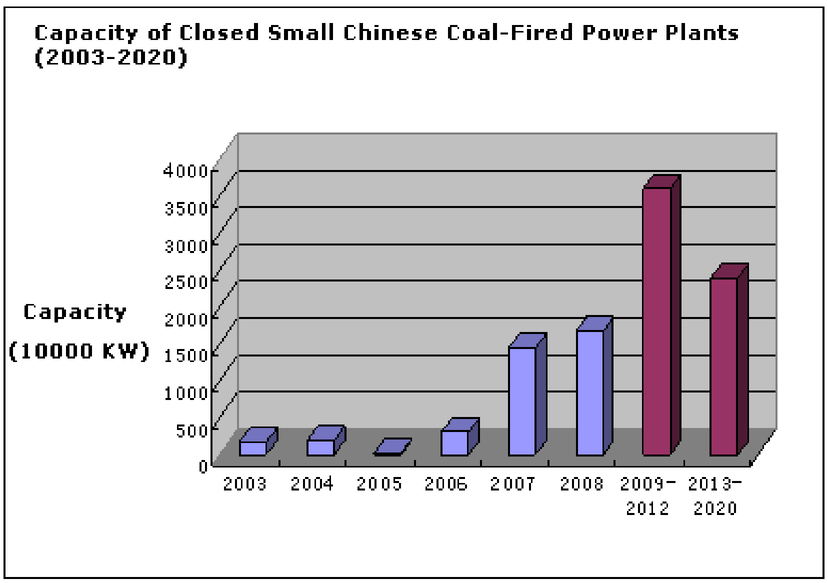


**Figure 2-9: Capacity of Closed Small Chinese Coal-Fired Power Plants**[24]

Based on data acquired from field research and interviews on a list of samples of coal-fired plants[25], the average employment number of one unit of coal-fired generation in China can be estimated as below:

The average number of employees reduced aroused by closing a small Chinese coal-fired power plant: **6.2 employees/MW.**

---

[24] Source: Data published by National Development and Reform Commission and Power Regulatory Commission. Data of 2008 are the actual data. Data of 2009 to 2020 are estimated.

[25] The samples include: 10 plants in Jiangxi province, 2 plants of North China Corporation in China Electricity Power Group, statistic data of closed plants in Shanxi province and nation.

Based on the above, the number of job lost aroused by closed small Chinese coal-fired power plants is shown as figure 2-14:

**Table 2-14: Employees Reduced aroused by Closed Small Chinese Coal-Fired Power Plants (2003~2020)**

| Year | Closed Capacity of Small Coal-Fired Power Plants (MW) | Affected Employees (1000 persons) |
|---|---|---|
| 2003 | 1,800 | 11.16 |
| 2004 | 1,840 | 11.41 |
| 2005 | 240 | 1.49 |
| 2006 | 3,140 | 19.47 |
| 2007 | 14,380 | 89.16 |
| 2008 | 16,690 | 103.48 |
| 2009 | 1,300 | 80.60 |
| 2010 | 1,000 | 62.00 |
| 2011 | 8,000 | 49.60 |
| 2012-2020 | 28,800 | 178.56 |
| **Total** | **97,890** | **606.93** |

Among which,

(1) from 2005 to 2008, the number of job lost:

34450 MW × 6.2 employees / MW= 213.6 thousand employees

(2) from 2009 to 2020, the number of employees that will be reduced:

59800 MW × 6.2 employees / MW = 370.8 thousand employees

Consequently, during 2005 to 2020, the number of employees reduced is expected to be about 584,4000 persons. If more plants with large capacity (such as 125 MW or 200 MW) are closed in the future, the total number of employees reduced will increase.

**2. Jobs Increased Number of large-scale and higher efficient coal-fired units**

Owing to the different requirements of the ‘Closing down the small and building up the large’ policy in different period, not all the closed-down units have been replaced by large units correspondingly. Suppose that the closed small thermal power plants units are replaced by large coal-fired units with the same installation capacity, we can get the average employment for new large power plant units according to the investigation.

Since a single unit of 300 MW has been taken as a minimum capacity for building new coal-fired plants, we may take this as a benchmark on a new large scale unit for a power plant. Based on field visits and statistic data on several coal-fired plants of HUANENG Power Group, the estimated average jobs per unit is **0.603 employees/MW.**

On the assumption of a concurrence replacement of new large units with small units, we may get the employment created in each year.

(1) from 2005 to 2008, the number of jobs created by new installation capacity:

34,450 MW × 0.60 employees / MW= 20,800 employees

(2) from 2009 to 2020, the number of employees that will be created:

59,800 MW × 0.60 employees / MW = 35,600 employees

**3. Overall Employment Effect of the 'Closing down the small and building up the large' policy**

From 2005 to 2020, the jobs lost and jobs created by 'Closing down the small and building up the large' policy is listed below:

- Jobs lost by closing down small-scale units: 584,400 persons.
- Jobs created by new installation capacity of higher efficient units: 56,400 persons.

So, the overall employment of the above two would be a net loss of 528,000 jobs in coal-fired industry from 2005 to 2020.

Although a net loss of jobs, low carbon development policy in coal-fired power industry would improve environmental and social benefits, including coal use efficiency, emission reduction of $SO_2$ and $CO_2$, which will improve the health loss of the residents. Based on our calculation, the policy would improve both economic efficiency and environmental benefits. For one thing, coal consumption would be reduced by 9.49 million tons due to implementing the policy during 2003~2020, and the emission of $SO_2$ and $CO_2$ would be reduced by about 15.18 million tons, and the environmental loss (such as cost caused by acid rain, air pollution etc.) will be reduced by about 75.9—303.6 billion yuan.

### 2.2.2 Employment Effect of De-sulfurization in Coal-Fired Power Industry

Although the Chinese government has been sparing no effort to promote the development of alternative energy, presumably, the clean and pollution-free energy, and the proportion of coal-fired electricity still holds a prominent place in China's energy structure even in present day.

As the figure shows that in China, the annual installed capacity is well above 70%. To cope with the air pollution problem associated with coal-fired electricity generating, China has begun to take a series of measures and the installation of desulfurization equipment should be one of them. In this section, we are going to examine closely the impacts on employment associated with the installation of desulfurization equipment in the context of input-and-output framework. Specifically, the discussion will be centered upon (1) the direct employment arising from the installation, maintenance and operation of desulfurization equipments; (2) the direct employment arising from the manufacturing the desulfurization equipments; and (3) the indirect employment and induced marginal employment arising from the expansion of industrial capacity.

**1. The situation of Desulfurization in China's Coal-fired Power Industry**

China's current capacity of power plants is about 600 GW, of which the 360 GW units in thermal plants have been installed with desulphurization facilities. Desulfurization equipment installation at different stages is shown below.

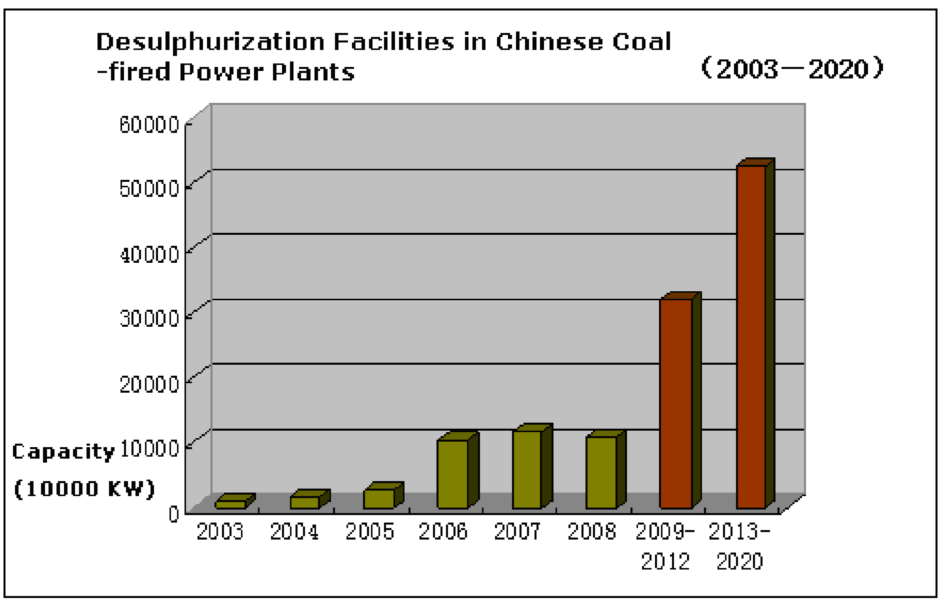


**Figure 2-10: Capacity of Desulphurization Facilities in Chinese Coal-fired Power Plants**

Source: Data published by National Development and Reform Commission and Power Regulatory Commission. Data of 2008 are the actual data.

**2. The Direct Employment Arising from the Reduction of Emission of $CO_2$**

**(1) Management and Maintenance of Installed Desulphurization Facilities**

As a rule, the newly added desulfurization equipment in the coal-fired power plants necessitates the supply of relevant personnel to take care of the equipment installation, management as well as maintenance. This research team conducted a random sample of 20 coal-fired power plants located in the eastern China, southern China, the western China, the central China, the southeast coast, the northeast, the southwest as well as the northwest areas. However, the research team successfully extracted data from 18 of all the 20 sampled spots. According to the data based on the 18 effective samples of coal-fired power plants, we found that for every unit of installed capacity, the average added employment is about 2600persons/kW. We further held a discussion with some authority figures and believed that the data we had obtained was very much consistent with the current state of operation of the desulfurization equipment. Thus we predict that during 2005-2020, the total number of professional personnel needed for operating, managing and maintaining the desulfurization equipment in China's power industry could be 31,800. (see Table 4, 5 and 6)

**Table 2-15: increased jobs Employees for the Management and Maintenance of Installed Desulphurization Facilities (2003-2020)**

| year | **Installed capacity of desulphurization facilities (MW)** | **Increased Employees (persons)** |
|---|---|---|
| 2003 | 7,600 | 198 |
| 2004 | 15,600 | 406 |
| 2005 | 26,500 | 689 |
| 2006 | 103,700 | 2,696 |
| 2007 | 116,000 | 3,016 |
| 2008 | 110,000 | 2,860 |
| 2009-2020 | 845,000 | 21,970 |
| **Total** | **1,224,400** | **31,835** |

**(2) Manufacturing the Desulfurization Equipments**

Desulfurization equipment manufacturing is a branch of industrial activities subsumed under the category of the general-purpose industries as well as the specific-purpose industries with the labor coefficient (the direct employment impact coefficient) 0.0142. That is to say, for every 100 million yuan increase in output value, 142 job opportunities would be created. By computing the investment in desulfurization equipment, we are confident to predict the value added and the impacts on possible job opportunities.

As China actively encourages the use of domestic desulfurization equipment, the costs of manufacturing and operating the desulfurization equipment fall dramatically. In the 1990s, the installation of desulfurization equipment in coal-fired power plants would cost the equipment per se and operation about 1,200 yuan per KW while at the end of 2005, the installation and operation of desulfurization equipment would cost only 360 yuan per KW. By the end of 2005, the installed capacity with desulfurization equipment totaled 26.5 million KW. If each kilowatt cost 360 yuan, the total cost of desulfurization equipment needed by the coal-fired power plants will be up to 9.5 billion yuan, creating about 13,500 direct job opportunities.

Based on the statistical data of 2005-2008 as well as relevant estimates on the installation of desulfurization equipment in China during 2009-2020 (see Table 4, 5 and 6), we can make an estimate of the direct employment effects by installing desulfurization equipment in China's coal-fired power plants. (See following table)

**Table 2-16: Impact on Direct Employment Created by the Manufacturing of Desulfurization Equipment (Unit: 1,000 People)**

| Sector | Year | Number of Employees |
|---|---|---|
| Operation and Maintenance of Desulfurization in Coal-Fired Power Generating | 2005~2008 | 9.26 |
| | 2009~2020 | 21.97 |
| Manufacturing of Desulfurization Equipment | 2005~2008 | 123.81 |
| | 2009~2020 | 142.98 |
| **Total** | **2005~2020** | **298.02** |

### 3. The Indirect Employment and Induced Employment of Desulfurization Industry

The indirect and induced employment coefficients are 0.0108 and 0.0502 respectively in the desulfurization equipment manufacturing business. In this way, we can evaluate the impacts of indirect and induced employment occasioned by increasing the investment in desulfurization manufacturing business. It should be noted that we do not take the indirect and induced employment impacts into consideration simply because the impacts are the results of operation and maintenance of desulfurization equipment.

According to *The Eleventh Five-Year Plan on the Treatment of Sulfur Dioxide in Coal-Fired Power Plants* published by China Development and Reform Committee and The Environmental Protection Agency, during the period specified by the 11th five-year plan, all of China's coal-fired power plants need the installation of desulfurization equipment with a total capacity of up to 100 million KW. China now has 221 coal-fired power plants. If, roughly 200 yuan will be invested for each KW in the desulfurization installation, China will generate a desulfurization equipment market of 27.4 billion yuan. Based on the output-input formula, this market will produce about 38,900 direct job opportunities and 29,600 indirect job opportunities. The total job opportunities will total 137,500 at the overall economic level.

**Table 2-17: Impact on Indirect and Induced Employment Created by the Manufacturing and Maintenance of Desulfurization Equipments (Unit: 1,000 People)**

| Sector | Year | Indirect Employment | Induced Employment |
|---|---|---|---|
| Operation and Maintenance of Desulfurization in Coal-Fired Power Generating | 2005~2008 | 14.13 | 17.57 |
| | 2009~2020 | 33.52 | 41.68 |
| Manufacturing of Desulfurization Equipments | 2005~2008 | 88.0 | 225.5 |
| | 2009~2020 | 101.6 | 260.5 |
| **Total** | **2005~2020** | **237.25** | **545.25** |

### 2.2.3 Overall Employment Effect of Coal-fired Power Industry

As a conclusion, the overall employment created by Desulfurization industry from 2005 to 2020 would be 1080.5 thousand persons. Among which,

- **The direct employment effect: 230,000 net jobs lost,** including jobs lost in closed small scale units of power plants, as well jobs created in new installation of large scale units, and maintenance and management of desulfurization facilities;
- **The indirect and induced employment effects: 782,500 jobs created** in product chain

effect of desulfurization related industry.

## 2.3 Wind Power Industry

Wind force is a kind of clean and renewable energy. Compared with traditional energy, wind power, independent from mineral energy, is not subject to the risks of fuel price, has a stable generation cost, and does not cause air pollution or carbon emission as fossil fuel does. Given these advantages, wind power has become a significant means of developing renewable energy in many countries. According to the statistics from WWEA (World Wind Energy Association), from 1995 to 2007, the global wind power market grew at an average annual rate of up to 27% with more than 20 billion US dollars of investment a year. The development of wind power in China has also maintained a sustained and rapid growth. The cumulative installed capacity of wind power in China ranks the fifth in the world in 2007. It is projected that by 2010, the total installed capacity of wind power in China will exceed 20 MKW, making China one of the largest wind power markets in the world. Moreover, China's total installed capacity of wind power is likely to reach 100 MKW by the year 2020. The fast growing wind power market in China will have positive impact on the employment in related industries.

### 2.3.1 Status Quo of the Development of Wind power in China and Its Trend

In order to press ahead the development of wind power and other clean energies, China implemented the Renewable Energy Law in 2006. In 2007, the newly established National Energy Administration has made nuclear power and wind power as the priority to improve the electricity structure and planned to build 6 super large wind farms of 10 MKW in some areas rich in wind resource like Inner Mongolia, Gansu, Xinjiang, Hebei and Jiangsu provinces. In 2008, the total installed capacity of wind power in China stood at 12.21 MKW with 8.94 MKW of grid-connected capacity and 10 MKW of installed capacity under construction.

According to China Wind Power Report[26], it is projected that wind power will play an important role as an alternative energy by 2010 with 24 billion KWh of electricity uploaded to grids. After

[26] Li Junfeng, Gao Hu, 2007 China Wind Power Report, Beijing, China Environmental Science Press,2007.10, p48-49

2020, wind power will show its strong cost advantage compared to other regular energies and it may account for more than 11% of the total installed capacity when China hit the medium-developed level. It could meet 5.7% of the national electricity demand. And also after 2030, wind power will become a major form of electricity construction in China due to the shortage of water resources as well as the mature technology and declining cost. It is also expected that by 2050, the installed capacity of wind power in China may hit 400-600 MKW, becoming the third largest source of electricity generation after thermoelectric and hydroelectric power.

Since 1990, the development of wind power in China has gained momentum (Fig.2-12). At the end of 2007, China ex-Taiwan has accumulated 6469 WTGS with a total installed capacity of 590.6MW, among which 330.4MW is newly installed. So the cumulative growth rate is 127%[27]. By the end of June of 2009, there are in all 166.53 MKW of installed capacity and 118.1 MKW of grid-connected capacity in China. With more than 240 wind farms established, it is estimated that about 60,000 jobs would be created by wind power industry in 2009. And from 1995 to the end of June of 2009, about 120,000 jobs or potential ones were already created by wind power industry in China.

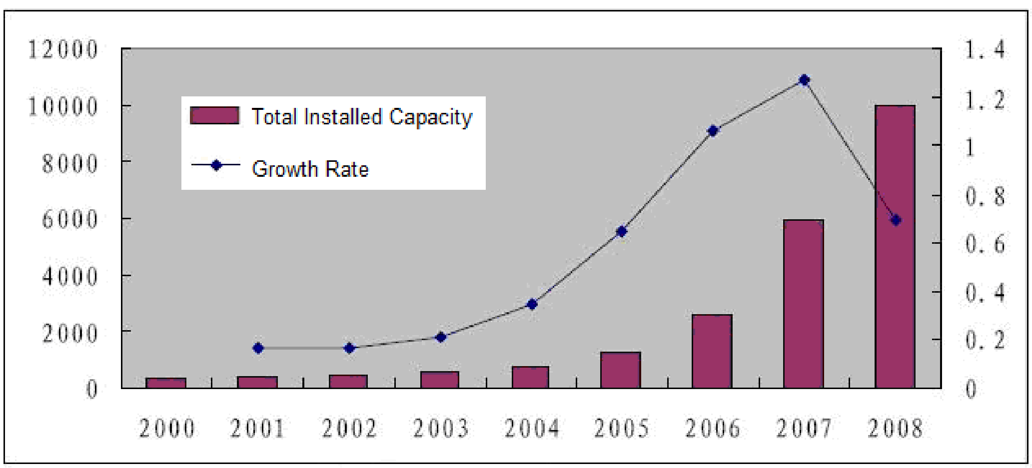


**Fig2-12: Growth of wind power installed capacity in China[28]**

The strong developing momentum of wind power market has also pushed forward the development of manufacturing and R&D activities of wind power equipment in China. At present,

[27] Shi Pengfei, "Statistics on China's wind power installed capacity ,2007 http://www.cwea.org.cn/upload/20080324.pdf

[28] Sources：http://www.okokok.com.cn

there are 185 wind power equipment manufacturers in China, including over 60 complete appliance manufacturers, large quantities of component manufacturers, such as fan blades that go with complete appliance, wind power generators and wind turbine gearboxes. These enterprises belong to the industries of electricity equipment, aerospace, heavy equipment and machinery manufacturing respectively. The development of wind power will also drive the manufacturing, R&D and technical service of these enterprises so as to create jobs indirectly.

### 2.3.2 Impact of Development of Wind Power on Employment in China

The wind power market, from the aspect of an industrial chain, is consisted of links ranging from upstream product design, manufacture, sales and maintenance service to the construction of electricity grid infrastructure. Industries related to wind power covers technical R&D, design, equipment manufacture (including fan blades, components and electricity generators), technical service, wind farm and construction of electricity grid infrastructure industries. The employment effects brought out by wind power can be calculated accordingly by breaking down the industrial chain. Manufacture and supply of wind power including the construction and operation of wind farms and electricity transmission bring about direct employment while the design, manufacture, sales, maintenance service and construction of electricity grid infrastructure bring about indirect employment. The income effects brought about by larger employment in these industries may lead to increment of demand in other industries, which is in the scope of induced employment effects.

The following information needs to be made clear so as to calculate the employment effects brought about by wind power.

- **The composition of investment of wind farm**

Based on the investigation data of a few typical wind farms, WTGS as the core equipment account for 60%-80% of the total investment, besides some other investment go into factory construction, land use, staff expense and so on.

- **The mainstream type of wind power equipment and its cost**

Before 2005, China on its own was only able to manufacture wind power equipment of 600 KW or lower while all the wind power equipment of more than 750 KW as well as some key components had to be imported from abroad. After the introduction of Renewable Energy Law, stimulated by policy and market force, the manufacturing and transfer of design technology of wind power equipment had gained momentum in China. China's ability of manufacturing independently also came into being. More and more wind power equipment of 750 KW to 1.5 MW became home-made. At present, a single wind power equipment of 600-850 KW accounts for about 70% of the total market share. With the uprising of technical performance and level of industrialization of the mainstream wind power equipment, it is estimated that the type of equipment with single-set capacity of 1.5 MW will dominate the wind power market in China in the years to come. And currently, as the global wind power market is dominated by that of 2-3 MW, China is still in the stages of independent R&D and design with the expectation of mass production after 2010. The author of this essay selects equipment with 850 KW of capacity as the mainstream type before 2010 and that with 1.5 MW of capacity as the mainstream type after 2010, and to calculate the installation cost per unit with this model so as to measure the employment effects brought about by investment in wind power equipment.

- **Domestic-made level of wind power equipment**

Before 2007, foreign manufacturers prevailed in the wind power equipment market of China. Aiming to enhance the percentage of home-made equipment by scale wind power, NDRC requires the construction of wind farms to reach the percentage of at least 70%. In order to avoid this policy, foreign equipment manufacturers with advanced technologies, attracted by China's cheap labor force, rained in China to build factories so as to get a share of the market. Moreover, receiving more support from the policies on renewable energy, the product of WTGS made by local enterprises has taken up a growing share in the newly added market. The figure rose from 29% in 2005 to 62% in 2008 (newly installed capacity accounts for 75%), leaving 38% of the share from foreign enterprises. Now, the top 5 enterprises in wind power market in China are namely Gold Wind, Sinovel, DEC, Vestas, Gamesa, among which the top 3 are all domestic enterprises (see Table 2-14).

The requirement of reaching a certain home-made percentage is beneficial to the employment effects brought about by wind power development. Taking China's import and also export of WTGS each year into consideration, China's export of WTGS from Q1 to Q4 in 2008 amounted to 10398 sets worthy of 211 million US dollars. To simplify the calculation, it is assumed that 70%

of the total installed capacity of wind power comes from domestic manufacturers and 30% from import. Based on this assumption, the author will further calculate the employment effects brought about by wind power development on other related industries.

**Table 2-14: Cumulative market share of WTGS manufacturers in China**

| | Manufacturers | capacity (KW) | Percentage accounting for domestic manufacturers and joint ventures of the year | Percentage accounting for the newly installed capacity of the year |
|---|---|---|---|---|
| Domestic manufacturers and joint ventures | Gold Wind | 2629050 | 35.02% | 21.63% |
| | Sinovel | 2157000 | 28.74% | 17.75% |
| | DEC | 1290000 | 17.19% | 10.61% |
| | Windey | 330250 | 4.40% | 2.72% |
| | NCWA | 250500 | 3.34% | 2.06% |
| | Shanghai Electric | 201250 | 2.68% | 1.66% |
| | MINGYANG Electric | 175500 | 2.34% | 1.44% |
| | XEMC | 128000 | 1.71% | 1.05% |
| | XINYU wind power | 82500 | 1.10% | 0.68% |
| | BEIZHONG wind power | 60000 | 0.80% | 0.49% |
| | others | 202170 | 2.69% | 1.66% |
| | subtotal | 7506220 | 100.00% | 61.76% |
| Foreign invested manufacturers | Gamesa | 1552500 | 33.41% | 12.77% |
| | Vestas | 1455200 | 31.32% | 11.97% |
| | GE | 637500 | 13.72% | 5.25% |
| | Suzlon | 347250 | 7.47% | 2.86% |
| | Nordex | 328750 | 7.08% | 2.71% |
| | Others | 325370 | 7.00% | 2.68% |
| | subtotal | 4646570 | 100.00% | 38.24% |
| Nationwide | total | 12152790 | | 100.00% |

Sources: Data from China Electricity Council and Chinese Wind Energy Association

- **Technical R&D and maintenance service of wind power**

The ability of independent R&D is relatively weak for Chinese wind power industry. Equipment manufacturers, majorly relying on the method of "technical introduction" to develop products, purchase the matured design technique and key components from advanced foreign manufacturers so as to enhance the technique of equipment installation and control system debugging and to increase the percentage of home-made components step by step. With domestic enterprises paying closer attention to increasing independent technical ability, the method of product developing has gradually turned into "jointly design" and "independent R&D". This shows that the future development of wind power market in China will create more job opportunities in the fields of technical development and equipment manufacture. Besides, domestic manufacturers of wind power equipment in China are still in the early period and are lacking behind of the advanced foreign equipment in terms of quality, so we can expect a rapid growth in sectors of technical support and maintenance service.

- **Electricity grid construction**

By the end of 2007, total installed capacity has exceeded 700 MKW, and it is likely to reach 900 MKW in 2010. Most of the wind resource in China lies in Northeast, Northwest and North part and marine area, but all these regions happen to be the areas that the grid is not able to cover now. China's wind farms are marked by large scale and high density. It is estimated that we will have 10-20 1MKW-level farms by 2015 and 5-6 10MKW-level farms by 2020. Large-scale and long-distance wind power transmission will require larger grid and more employment. The demand, mostly economic activities, is led by the integration of wind power into grid, including manufacturing of transmission equipment, grid infrastructure construction, maintenance of grid and so on.

### 2.3.3 International Experiences on Wind Power Development Stimulating Employment

According to the estimation of 2050 Energy Technology Perspective: Scenarios and Strategies published by IEA, from 2010 to 2050, the global wind power will grow by 70 MKW each year on average reaching installed capacity of 4.06 billion KW by 2050. With the rapid growth of wind power market and more countries benefiting from clean electricity, people became to realize the huge economic benefits and the employment effects contributed by wind power industry. In this connection, some international institutions have calculated the employment contributed by wind power.

- **Worldwide**

It is projected by GWEC that by 2010 the global installed capacity will add up to 16 MKW which will enable 1 million people to be engaged in industries related to wind energy. Further more, up to 3 million people will go into industries related to wind energy by 2050.

Base on the trend of development and the technical level of the wind power market, "Wind Force

12", a report jointly published by EWEA and Greenpeace, pointed out that the global installed capacity will reach 1.26 billion KW by 2020 accounting for 12% of the energy supply of the world with 1.8 million jobs created by wind power related industries.

- **European Union**

According to the report, entitled, 'Wind at Work – wind energy and job creation in the EU' published by EWEA at the beginning of 2009, the sector of wind energy in EU employed 154,000 people in 2007. And by then, the total installed capacity of WTGS of the EU member states stood at 57.139 MKW accounting for almost 4% of the energy supply in EU.

Based on statistics from EERA, in 2002, jobs created by wind power industry (including manufacturing, installation and maintenance of wind power equipment) in Europe had already topped over 70,000. In 2006, the number of people working in wind power industry in Germany had arrived at 82,100 with a total of 20.58 MKW of installed capacity.

It is also stated in the report of 'Wind at Work – wind energy and job creation in the EU' published by EWEA that by 2020, the development of wind energy will provide EU with 325,000 job opportunities and by then the total installed capacity in EU will reach 18 MKW.

- **The United States**

According to a survey made by Worldwatch Institute, generating one billion KWh of electricity by coals or nuclear fuels provides only 100-116 job opportunities while a wind farm can provide 542 job opportunities generating the same amount of electricity.

One of the researches in American New Energy Policy Facility indicates that for every MKW wind power equipment produced, it will create: 3,000 jobs in manufacturing industry, 700 in installment, 600 in operation and maintenance. Among these industries, manufacturing accounts for 70% of the total. In 2008, the installed capacity of wind power in the US registers 25.17 MKW, overtaking Germany (23.90 MKW) as the No. 1 in the world. In the States, the number of jobs in wind power industry hit 85,000 with 35,000 created that very year.

Based on the research, we can measure the contribution rate of installed capacity to employment (table 2-15):

**Table 2-15: Job creations in major wind power economies in the world**

| No. | Year | Wind power Economies | Installed capacity | Employment figures |
|---|---|---|---|---|
| 1 | | US | per one MKW | 4300 |
| 2 | 2002 | EU | 23.098 MKW | 72275 |
| | 2006 | Germany | 20.58 MKW | 82100 |
| 3 | 2007 | EU | 57.139 MKW | 154000 |
| 4 | 2008 | Globe | 120.791 MKW | 400000 |
| 5 | 2008 | US | 25.17 MKW | 85000 |
| Total | | | 247.778 MKW | 797675 |
| **Number of jobs created / KW of installed capacity at present** | | | **32 people / 10000 KW** | |
| 5 | 2010 | Globe | 160 MKW | 1000000 |
| 6 | 2020 | Globe | 1260 MKW | 1800000 |
| | 2020 | EU | 180 MKW | 325000 |
| Total | | | 1600 MKW | 3125000 |
| **Number of jobs created / KW of installed capacity in the future** | | | **20 people / 10000 KW** | |
| 7 | 2050 | Globe | 4060 MKW | 3000000 |
| **Number of jobs created / KW of installed capacity in the future** | | | **7 people / 10000 KW** | |

As indicated, with the development of science and technology and the enhanced operation of wind power, the number of jobs needed per unit of installed capacity will go down 38% by 2020 and decline 78% by 2050 compared with the number in 2008.

### 2.3.4 Analysis of the Employment Effects of China's Wind Power Industry

In this part, the author analyzes the wind power industry's impact on boosting employment through such major links as wind power generation and supply, wind power equipment manufacturing and wind power technical service. In this research, the number of jobs created by unit installed capacity of wind power is calculated through statistics from the typical companies with the bottom-up method. Then the author uses input-output analysis to calculate the indirect employment effects and induced employment effects. There are two time angles: firstly, the author calculates the existing employment effects through data of the past and the status quo, which can be gained from wind power generation and wind power equipment manufacturers; secondly, the author relies on the future development in wind power market to predict the employment level in the future wind power generation and manufacturing industry. The data required comes from the calculation of the development scale of the future wind power industry in China.

In order to figure out the employment effects of wind power industry in the context of the entire economic system, the author relies on the “Table of 2005 input-output analysis” published by National Statistics Bureau. The table divides the macro economy into several units. With the help of the input-output data, we can get each unit’s investment in equipment manufacturing and electricity-generating process in industries related to wind power. We can also get the overall employment effects per out-put value of wind power industry offers to the economic system. Wind power industry is classified as electrical and thermal generation and supply industry. Rather than being directly represented in the input-output table, the WTGS manufacturing industry is classified as a subunit in the general and specialized equipment manufacturing industry. In addition, the technical development and the maintenance service of wind power are classified as scientific research industry and comprehensive technical service industry.

According to the “Table of 2005 input-output analysis”, the indices of employment effects of related sectors are calculated as follows:

**Table 2-16 Coefficients of employment effects of major sectors**

| Industries related to wind power | Industry in I-O Table | Direct Coef. | Indirect Coef. | Induced Coef. |
|---|---|---|---|---|
| Wind power industry | electrical and thermal generation and supply industry | 0.0114 | 0.0174 | 0.0217 |
| Wind power equipment manufacturing industry | general and specialized equipment manufacturing industry | 0.0142 | 0.0101 | 0.0259 |
| Wind power R&D and service industry | scientific research industry | 0.0492 | 0.0122 | 0.0220 |
| | comprehensive technical service industry | 0.035 | 0.0148 | 0.0206 |

**（1）direct employment effects**

In this paper, we define the wind power industry on a broad basis, including (1) the added jobs offered by the construction of the wind power farms and the increase in the electricity supply, which refers to the industry of “electrical and thermal generation and supply industry”, (2) WTGS and components manufacturing are classified as “general and specialized equipment manufacturing industry” in the statistical system, (3) technical R&D and maintenance service in wind power industry etc.

- **Wind power generation（wind power generation and supply）**

Since the current input-output system of China does not issue the detailed information of wind power generation and supply, we need to extrapolate the employment in this sector.

According to the research statistics from typical wind power enterprises, it can be calculated that per unit installed capacity of wind power creates jobs of 15～20 people/1000KW. Based on this, the total number of jobs in wind power enterprises from 2005 to 2010 can be estimated. Using the global statistics of jobs created per unit installed capacity of wind power in the future the number of employees in the wind power industry from 2011 to 2020 can also be estimated. Results from the estimation are shown in Table 2-17.

**Table 2-17: Jobs created in manufacturing and supply of wind power from 2005 to 2020**

| Year | Installed capacity of wind power（10000 KW） | Job opportunities（thousand person） |
|---|---|---|
| 2005 | 126.3 | 1.9～2.5 |
| 2006 | 259.9 | 3.9～5.2 |
| 2007 | 590.3 | 8.9～11.8 |
| 2008 | 1215.3 | 18.2～24.3 |
| 2009 | 2115.3 [29] | 31.7～42.3 |
| 2010 | 2500 [30] | 37.5～50.0 |
| 2011~2020 | 12000 [31] | 111.6～148.8 [32] |

- **Wind power equipment manufacturing industry**

[29] It is estimated based on the data from January to June, 2009.
[30] It is the high target data published by Wind Power Report 2008.
[31] It is the high target data published by Wind Power Report 2008.
[32] It is achieved based on the assumption that the total employment per 10000 KW will decrease 38%.

WTGS and components manufacturing are classified as “general and specialized equipment manufacturing industry” in the statistical system. According to Table 2-16, the indirect employment effects index in this industry is 0.0101, which means that the investment of a billion RMB can offer 101 jobs. According to statistics, in 2006 the average market price for WTGS is approximately 4000yuan/kW[33]. A research about the public-traded WTGS manufacturer “Gold Wind Science & Technology Co. Ltd” indicates that the cost of various types of WTGS Gold Wind sold between 2005 and 2007 was approximately 2600yuan/kW[34]. Thus it can be calculated that between 2005 and 2008, the cost of WTGS should be anywhere between 2500yuan/kW and 4000yuan/kW. And also it can be calculated that the newly installed capacity of 1GW can provide 36～57 jobs directly in the wind power industry and 27～43 job opportunities in those industries directly related with equipment manufacturing industry in supply chain, bringing 65～104 other job opportunities to the economy in industry expansion process. [35] Every year, part of our new WTGS is imported. This share should not be taken into consideration when studying WTGS’s effects on boosting the job market. Thanks to the statistics by researchers, the author was able to calculate the home-made new capacity of the wind power during 2005 and 2008. As shown in Table 2-18:

**Table 2-18: Newly installed capacity and domestic production**

| Year | newly installed /GW | Share of domestic production /% | domestic production of newly installed /GW |
|---|---|---|---|
| 2005 | 50.2 | 29.4% | 14.76 |
| 2006 | 133.3 | 45.0% | 59.99 |
| 2007 | 330.4 | 57.5% | 189.98 |
| 2008 | 625 | 75.6% | 472.50 |
| 2009 | 900[36] | 80%[37] | 720 |
| 2010 | 633[38] | 80% | 506.4 |

Source：Shi Pengfei, years of statistics on China’s installed capacity of wind farms.

33 http://www.newenergy.org.cn/Html/0081/200817_15065.html.
34 In 2005, 2581yuan/kW; in 2006,2643yuan/kW;in 2007,2603yuan/kW.
35 Assume that no big shift in economic structure from 2006 to 2008, the calculation’s based on input-output table 2005.
36 It is estimated based on the data from January to June, 2009.
37 It is the projection data issued by NDRC’s new emery industries development plan, the 2010 data in the table is the same with this projection.
38 It is the high target data published by Wind Power Report 2008.

According to the prediction in China's wind power report of the future newly installed capacity of wind power, from now on to 2010 the installed capacity of wind power will increase by 100GW/Y under the low development scenario, with an annual growth rate of 15%; by 133GW/Y under the medium development scenario, with an annual growth rate of 15%; by 633GW/Y under the high development scenario, with an annual growth rate of 60.9%[39]. On the assumption that there will be no major shift in our economic structure from now on to 2010, according to the input-output table, under the high development scenario the manufacturing of the new wind power equipment will create 18 thousands to 29 thousand jobs directly in 2010.

- **Technical R&D and maintenance service in wind power industry**

In countries like Denmark which enjoy mature wind power technology and wind power market, the jobs directly created by wind power industry include not only those in the wind power generation and supply、WTGS manufacturing, but also those in wind-power-related R&D and consultation industry. However, China developed wind power at a reletively late start, and most of the technologies were imported from other countries. Meanwhile, investment in R&D has been increasing over the recent years; in this analysis the jobs in R&D and consultation industry are regarded as by wind power related industry.

According to 2005 input-output table, we can calculate the employment coefficient of power generation and supply industry with scientific research industry and comprehensive technical service industry is 0.000759; and the employment coefficient of general and specialized equipment manufacturing industry with scientific research industry and comprehensive technical service industry is 0.000539. Based on these, we can estimate that in 2005, the number of job opportunities created in sectors R&D and consultant activities in wind power industry in China is about 146～198.  In 2006, the number grows to 340～472, in 2007, the job opportunities are about 847～1193.

To sum up, we can calculate the total number of the created job opportunities in wind power generation sector, wind generation equipment manufacturing and Technical R&D and maintenance service in wind power industry of China from2005 to 2020 as shown in table 2-19.

39 Source: China Wind Power Report 2008, China Environmental Science Press, 2008.10, p62

**Table 2-19: Direct employment effects created by wind power industry from 2005 to 2020(unit: 10 thousand person)**

| Industry | Year | Employment |
|---|---|---|
| Wind power production and supply | 2005~2010 | 10.2~13.6 |
| | 2011~2020 | 11.16～14.88[40] |
| Wind power equipment manufacture | 2005~2010 | 7.1~11.2 |
| | 2011~2020 | 19.2~30.3[41] |
| Wind power R&D and technical service | 2005~2010 | 0.94~1.33 |
| | 2011-2020 | 1.47~2.14 |
| **Total** | **2005~2020** | **50.51～73.45** |

**（2）Indirect and induced employment effects**

The induced employment refers to the increase of revenue or consumption in related industries caused by investment changes in the industry chain, such as wind power activities, manufacturing of wind power equipment and technology service as well as its ripple effects. The indirect and induced effect is displayed as follows:

**Table 2-20: Indirect and induced employment created by wind power industry from 2005 to 2020 (unit: 10,000 person)**

| Industry | Year | Indirect Employment | Induced Employment |
|---|---|---|---|
| Wind power production and supply | 2005~2010 | 15.6~20.8 | 19.4~25.9 |
| | 2011-2020 | 17.0~22.7 | 21.2~28.3 |
| Wind power equipment manufacture | 2005~2010 | 5.0~8.0 | 12.9~20.4 |
| | 2011~2010 | 13.6~21.5 | 35.0~55.2 |
| Wind power | 2005~2010 | 0.32~0.52 | 0.53~0.75 |

40 It is achieved based on the assumption that the total employment per 10000 KW will decrease 38%.

41 We assume during 2011~2020, the manufacture cost in wind power equipment manufacturing industry will decrease 30% compared with the lever during 2005~2010.

| | | | |
|---|---|---|---|
| R&D and technical service | 2011-2020 | 0.57~0.83 | 0.82~1.20 |
| **Total** | **2005~2020** | **52.09~74.35** | **89.85~131.75** |

## 2.4 Solar Power

Solar power generation includes generation by solar photovoltaic and solar thermal energy. However, solar thermal generation has not been commercialized in China yet, there are only a few demo projects. As a result, our analysis of the impact of solar power generation on employment will focus on how solar photovoltaic generation affects employment, including solar photovoltaic production and solar photovoltaic power generation.

### 2.4.1 Current Status and Development Trend of Solar Power Generation

Solar energy is the most primitive energy, and almost all energies in the world come directly or indirectly from solar energy. As solar energy could transfer into many other forms of energy, it is widely used (See Figure 2-13). Solar energy is used in the form of solar thermal energy, solar photovoltaic, natural solar light, etc.. Solar power generation includes photovoltaic generation and solar thermal generation[42].

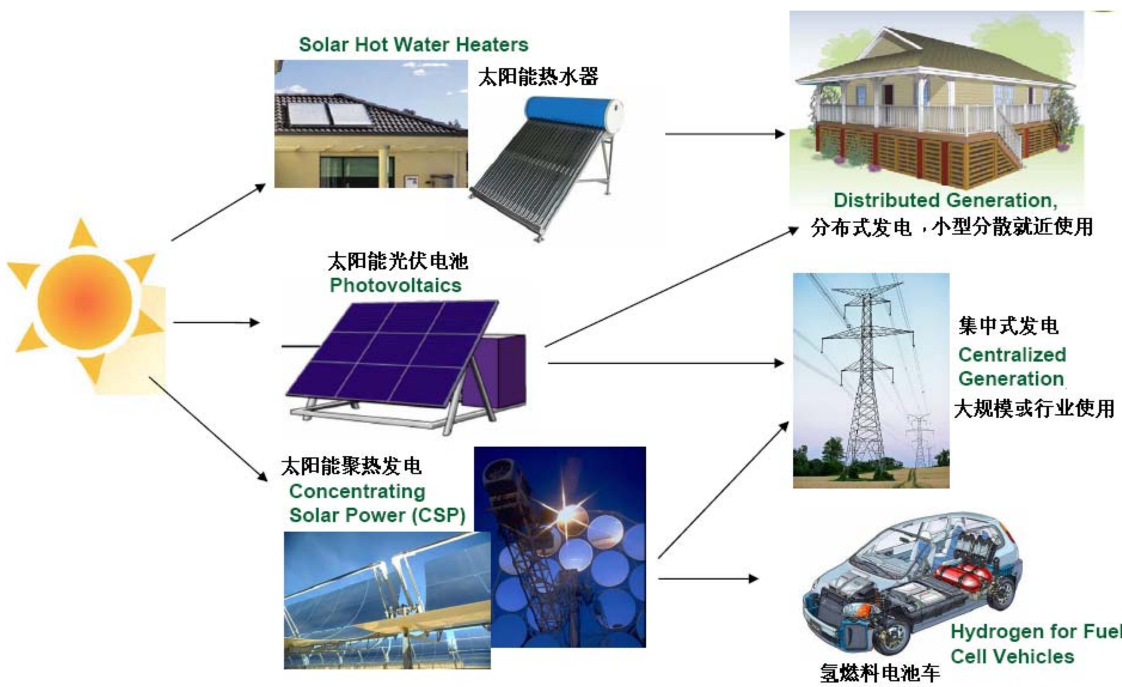


**Figure 2-13: Different ways of utilizing solar energy**

[42] Solar thermal generation is harnessing solar thermal energy with a heat collector to run the generator to generate electricity. Solar photovoltaic generation transfers solar radiation directly into electricity without transferring solar light into thermal energy.

China is rich in solar energy resource, with totally stock equaling 2.4 trillion tons of coal equivalent. Tibet, Qinghai, Xinjiang, Gansu, Ningxia and Inner Mongolia are the provinces hat have specially rich solar energy resource (See figure 2-14).

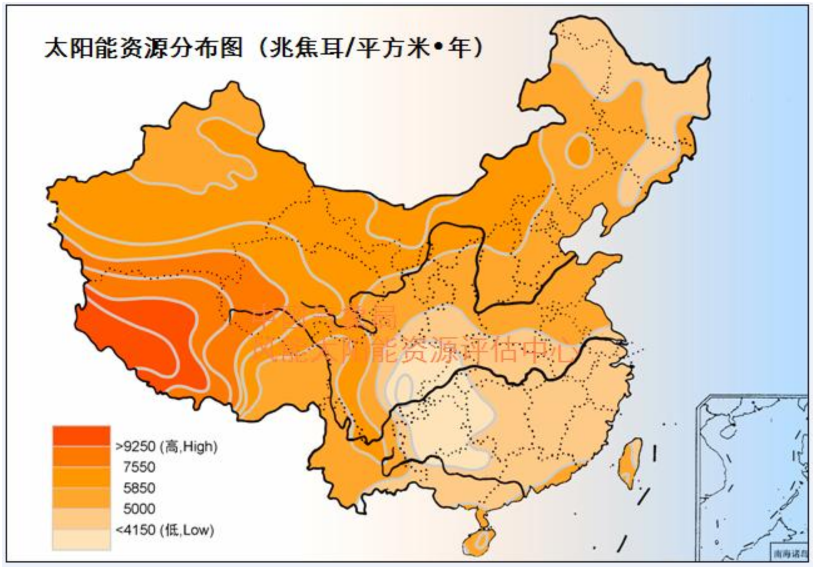


**Figure 2-14：Solar Energy Resource in China (in GJ/m2*year)[43]**

With the emerging global energy crisis, solar power becomes focus of attention in many countries. In recent years the proportion of solar energy utilization and generation has being increasing. Solar photovoltaic industry is developing rapidly and draws lots of attention. With many years development, photovoltaic generation has become a mature and proven technology. Globally photovoltaic generation installed capacity has amounted to 2392MW, an annual increase of 40%（see figure 2-15）. As photovoltaic cells efficiency increase and its cost decreases, it is estimated that until 2010, photovoltaic will grow at the rate of at least 30%, while annual sales amount will increase from 7 billion US dollars in 2004 to 30 billion US dollars in 2010. According to European Photovoltaic Industry Association (EPIA), by 2020, global photovoltaic production will reach 40GW, and solar photovoltaic generated electricity will reach 1% of total generation. The development of photovoltaic generation will inevitably stimulate employment in the industry as well as in related industries.

[43] Data source: Solar and Wind Energy Resource Evaluation Center, China Meteorological Administration, http://cwera.cma.gov.cn/cn/

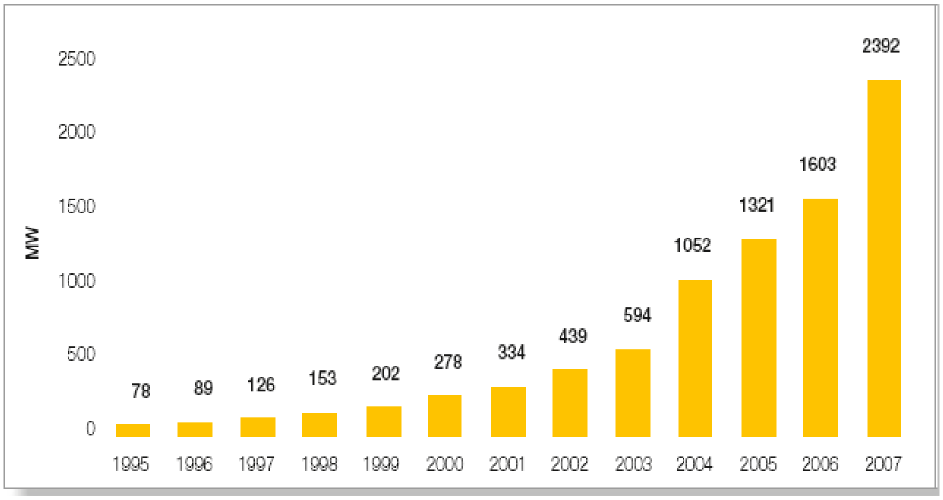


**Figure 2-15 Global Installed Capacity of Solar Photovoltaic Generation (MW)[44]**

Since 2003, along with global photovoltaic market development, China witnessed tremendously rapid progress in its photovoltaic manufacture industry. Annual solar power cell production in China amounted 1188MW, enabling the country to exceed Japan and Europe and become the largest photovoltaic manufacturer in the world. As silicon production and technology advances in the country, photovoltaic manufacture industry started to mature in China[45]. By December 2008, there were more than 100 photovoltaic generation project constructed and connected to grid. There were more than 500 photovoltaic companies, out of which 40 plus on materials, 70 plus on silicon ingots and silicon wafers, 30 plus on cells. A number of companies, such as Wuxi Shangde, Changzhou Tianhe, Baoding Tianweiyingli, Nanjing Zhongdian, Jiangxi Saiwei, have stepped into international market. Wuxi Shangde and three other companies has production that rank the top 16 in the world. The development of these enterprises has provided large amounts of job opportunities.

Photovoltaic generation industry started to pick up in 1970s in China and surged rapidly in the recent years (figure 2-16). By the end of 2007 total installed capacity reached 100MW. Total generated amount reached 1.1 gigawatts, accounting to 27.5% of the total amount generated globally. Since 2008 photovoltaic industry maintained high growth rate, and total generated

[44] Green Peace, European PV Industry Association (EPIA), "Solar Generation V – 2008: Solar electricity for over one billion people and two million jobs by 2020"
[45] "2008-2010 China Solar PV Generation Industry Analysis and Investment Consulting Report", China Investment Consulting Website. http://www.ocn.com.cn/reports/2006103guangfufadian.htm

amount is expected to reach 2GWh.

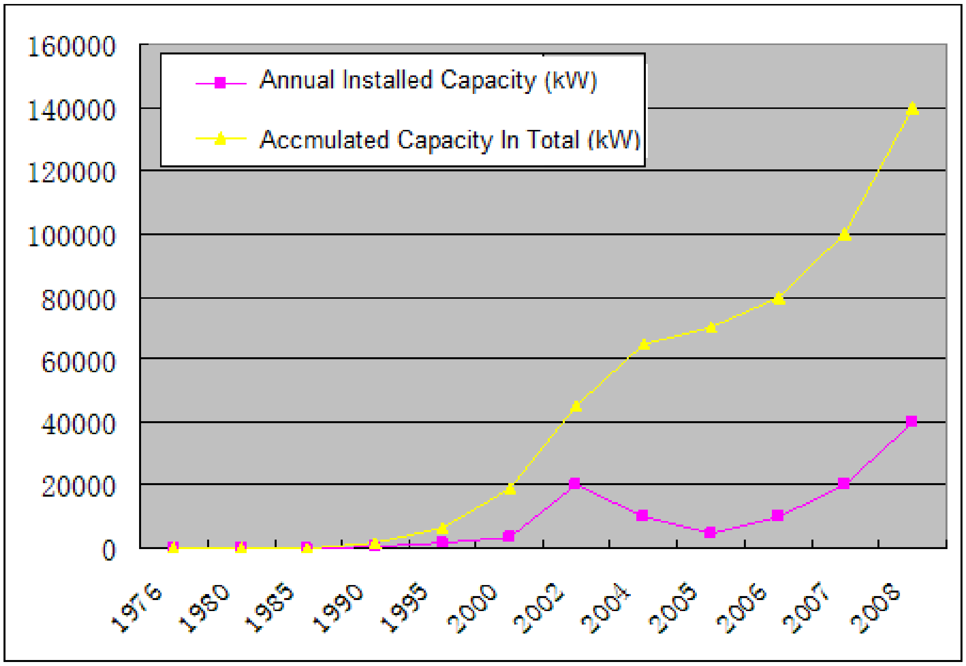


**Figure 2-16: Development Trend of Solar Photovoltaic Generation in China （1976-2008）**

Data Source: "China Photovoltaic Industry Development Report 2007" and Statistics from Energy Research Institute of NDRC

Due to technology and cost barriers, in China solar power generation is far less developed as photovoltaic manufacture industry, and the country is witnessing a abnormal status of "both technology and market are outside the country". From 1990 to 2007, solar cells production increased by 1641 times, while photovoltaic installed capacity increased only by 39 times. During 2004-2006, export amount of solar cells took up to 80%, 96.7% and 95% of total production in those three years respectively, and only a very small percentage were installed and utilized in China. With the policy incentives for low-carbon development, domestic demand for solar power generation is expected to increase rapidly and investment and employment are expected to increase with the expected surge.

Solar power generation is used for a wide range of purposes in China (see figure 2-17). Take urban building energy efficiency as an example, China construct 2 billion square meters new building annually, accounting for nearly 50% of global building area, and building energy consumption accounts for 20% of total energy consumption of all sectors. Photovoltaic buildings are expected to appear broadly in many large cities with the low-carbon economy development. Shanghai launched “100,000 Solar Roofs Program” in 2005 and marked the starting point of large amount application of solar power in buildings in China. It is estimated that by 2010, China will construct about 1000 roof photovoltaic generation projects with total capacity of 50MW. By 2020 the number are expected to increase to 20,000 projects and 1000MW. Secondly, the vast area of western China with low population density and very rich solar resource is the ideal place for developing household photovoltaic generation system and ground photovoltaic generation plants. The market demand is estimated to be 3000MW in total. It’s estimated that remote rural area photovoltaic generation capacity will reach 150MW by 2010 and 300MW by 2020. Besides, photovoltaic generation has good potentials to be used for communication, meteorology, long distance pipes, railways, and freeways. It’s estimated that these sectors will witness total photovoltaic capacity of 30MW by 2010 and 100MW by 2020. In summary, photovoltaic generation capacity in China is expected to reach 600MW by 2010 and 20000MW by 2020.

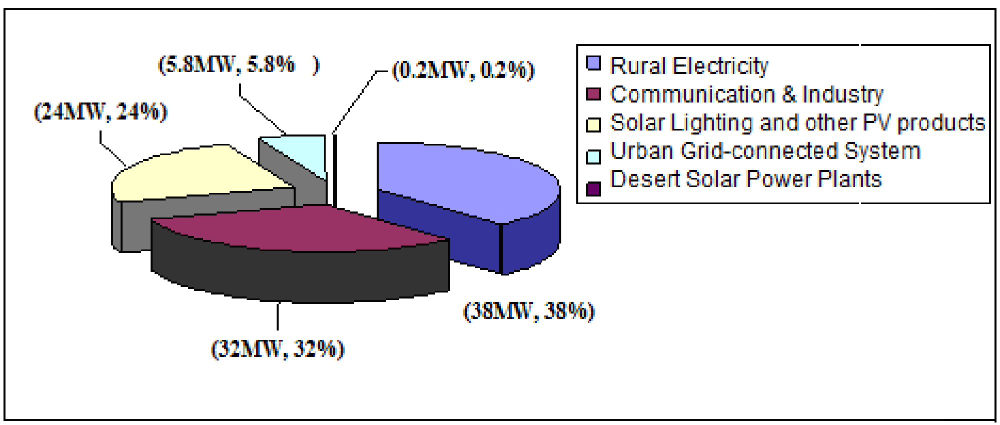


**Figure2-17： Utilization of Solar Power in 2007**

According to “Medium and Long Term Plan of Renewable Energy”, China aims to reach 1.8GW installed capacity of solar power generation by 2020, and reach to 600GW by 2050. It’s estimated that by 2050, renewable energy installed capacity will take up to 25% of total capacity, while photovoltaic generation will contribute to 5%. In the coming few decades, solar power installed capacity compound growth rate will be as high as above 25%[46].

---

[46] “2008-2010 China Solar PV Generation Industry Analysis and Investment Consulting Report", China Investment Consulting Website. http://www.ocn.com.cn/reports/2006103guangfufadian.htm

### 2.4.2 Direct Marginal Employment Effect of Solar Power Industry

The supply chain of photovoltaic generation industry consist five components: silicon material, silicon sheet, solar cells, solar panels, and photovoltaic generation. Currently China has developed a complete industrial chain from material extraction and processing to final products for polycrystalline silicon, silicon chip, solar cells and solar panels. This report will provide introduction to all aspects of photovoltaic industrial chain and analyzed their impact on employment.

There are many sectors related with PV industry chain. According to 2005 Input-output Table we derive marginal employment effect of solar power generation as the following:

**Table 2-21: Marginal Employment Coefficient of Solar Power Related Sectors**

| Solar power Related Sectors | Industries in I-O Table | Direct Coef. | Indirect Coef. | Induced Coef. |
|---|---|---|---|---|
| Solar PV generation | Production and Supply of Electric Power, Steam and Hot Water | 0.0114 | 0.0174 | 0.0217 |
| Solar panels Production | Electronics, Machinery and Equipment manufacturing | 0.0101 | 0.008 | 0.0473 |
| | Telecommunication Computer and other electronic equipment manufacturing | 0.0084 | 0.0095 | 0.0323 |
| | General and special Equipment manufacturing | 0.0142 | 0.0101 | 0.0259 |
| | Scientific research industry | 0.0492 | 0.0122 | 0.0220 |
| | Comprehensive technical service industry | 0.035 | 0.0148 | 0.0206 |

**(1) Polycrystalline Silicon Material Industry**

So far, the crystalline silicon photovoltaic cells still dominate the solar cell market. In the end of 2007, crystalline silicon PV cells' market share are up to 91.25%, which means the manufacture of polycrystalline silicon is the most important one within the photovoltaic industrial chain. In the industrial chain of crystalline silicon solar panel production, the major barrier is the production of hyper-pure polycrystalline silicon. As it is the major material for producing solar panels, the silicon price will directly influence solar panel production. Among most domestic photovoltaic companies, silicon material usually contribute to more than 56% of the total cost for solar panel production and about 30% of grid-connected generation cost.

With the development of polysilicon production technology, the production of silicon materials increases rapidly in recent years. According to various statistic data, China's polysilicon production capacity grows from less than 200 tons in 2005 to 6,000 tons in 2008. The total production of polysilicon was 80 tons in 2005, while in 2008 it grows to nearly 5000 tons. We may infer the basic development of China's silicon industry from table 2-22 below.

**Table 2-22：Basic information of China's polysilicon industry (2005～2008)**

| Year | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Total Production（tons） | 80 | 290 | 1130 | 4515 |
| Sales Income（100 million YUAN） | 0.4 | 5.8 | 22.6 | 85 |
| Employment（person） | 1000 | 3600 | 7000 | 12000 |

### （2） Silicon Ingot/Silicon Chip Industry

The manufacture of PV silicon ingot/silicon chip is the second process in photovoltaic industrial chain. In recent years, the PV silicon ingot/silicon chip industry grows rapidly. By the end of 2008, there are more than 70 firms in this field. (In this report, we take the manufacture of silicon ingot/silicon chip as a whole industry chain.) The basic information on its production, sales income and employment are listed in table 2-23.

**Table 2-23：Basic information of China's photovoltaic silicon ingot/silicon chip Industry (2005～2008)**

| Year | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Total Production（tons） | 2516 | 5670 | 11800 | 20000 |
| Sales Income（100 million YUAN） | 25.16 | 136.1 | 283.44 | 480.04 |
| Employment（person） | 2360 | 7700 | 13000 | 20000 |

### (3) PV Panel/ Module Package Manufacture

Since 2002, China's annual production of solar PV cells to grow rapidly. To 2006, the production reached 438MW, accounting for 17.1% of global production 256.2MW, which was more than the United States' production of 179.6MW, becoming the third biggest PV solar producer of the world, only next to Japan (926.9MW) and Europe (680.3MW). In 2007, the production reached 1088MW, accounting for 27.2% of global production, more than Japan (920MW) and Europe (1062.8MW), to become the world's largest solar cell producer. In 2008, output continued to increase, reaching 2.6 million kilowatts, accounting for about 1/3 of global production (see Table 2-24).

**Table 2-24 Solar Panel Production during 1999-2008 (Unit: MW)**

| Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| Production | 2.5 | 3 | 4.6 | 6 | 12 | 50 | 145.5 | 438 | 1088 | 2600 |

Solar PV cells must be packaged before application, thus module package is also a very important sector in photovoltaic industrial chain. The technology of package of solar cells is relatively simple and requires less investment. So it is easy to start a business in this area and suitable for small firm to compete. According to ENF Solar's statistics, in 2007, there are about 172 solar cell module packaging companies in China with a total packaging capacity more than 2000 MWp. Solar cell module package is relatively labor-intensive compared with other sectors, so China has to package for part of foreign battery assembly. China's solar cell module development from 2005 to 2008 can be shown in Table 2-25.

**Table 2-25：Basic information of China's solar PV panel/module Industry (2005～2008)**

| Year | 2005 | 2006 | 2007 |
|---|---|---|---|
| Total Production of PV solar cells/module（tons） | 284 | 721 | 1717 |
| Sales Income（100 million YUAN） | 87 | 252.4 | 549.4 |
| Employment of PV cells Manufacture（person） | 1500 | 4800 | 11000 |
| Employment Module Manufacture（person） | 2650 | 9000 | 25000 |

Based on the above information and "China Solar PV Industry Report（2004～2005）" and "China Solar PV Industry Report（2006～2007）", we can derive the direct employment data created by solar PV industry during 2005 to 2008. (See Figure 2-26)

**Table 2-26：Directly Created Jobs of Solar PV Industry (2005～2007) (person)**

| Sector | Direct Employment | | |
|---|---|---|---|
| | 2005 | 2006 | 2007 |
| Polycrystalline Silicon Materials | 1000 | 3600 | 7000 |
| Silicon Ingot/Silicon Chip | 2360 | 7700 | 13000 |
| Solar PV Cell Panel Manufacture | 1500 | 4800 | 11000 |
| Module | 2650 | 9000 | 25000 |
| System Engineering and Market Servicing | 2000 | 2600 | 3000 |
| Key Components（inverter＋accumulator） | 500 | 1000 | 1500 |
| Special Materials（Glass，EVA，silver and aluminum paste etc.） | 500 | 1800 | 2500 |
| Lightening, Gardenlamp and Other Related Consumables | 3000 | 8500 | 15000 |
| R&D Activities | 300 | 500 | 800 |
| **Total** | **13810** | **39500** | **82800** |

Data sources：“China Solar PV Industry Report（2004～2005）” ; “China Solar PV Industry Report（2006～2007）”.

**(4) Solar Power Generation**

Due to cost restraints, solar power generation capacity is still limited in China. By the end of 2005, total installed capacity of photovoltaic generation was only 70MW, out of which 5MW was newly-developed in 2005. In 2008 the number reached 140MW, with about 40MW net increase in 2008.

In 2006, the initial investment for a solar PV system was around 50,000 Yuan/kWp. In grid-connected solar PV system construction investment, the cost for solar modules (including mount) is about 66%; the cost of inverter, transformer, power monitoring and cable account for about 20%; component transportation accounts for about 1.6%; installation adjustment investment is about 3.6%; other investment including feasibility study, project design, feed in grid test, tax and other costs will account for about the rest 8.8%. Therefore, solar PV panel manufacture industry is a major industry providing inputs to PV system construction. In addition, solar PV power generation system will drive scientific research industry and comprehensive technical service industry to absorb more employment.

Because about 2/3 of total initial construction investment of solar PV power system flows into solar PV panel manufacture industry, part of the employment created by solar PV power generation will overlap with solar PV cells industry. However, considerable part of total solar cell production is sold to foreign corporations. The employments induced by these two sectors are not equivalent. In this part, we will analyze the direct employment created in solar PV system construction. We will derive the direct jobs related with solar PV system construction investment (table 2-28) based on the solar PV power generation targets (2005～2020) (see figure 2-27) .

**Table 2-27：China’s Solar PV Power Generation Target (2005～2020)（Unit：MWp）**

| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2020 |
|---|---|---|---|---|---|---|---|
| Newly Installed Capacity of Solar Power | 5 | 10 | 20 | 40 | 60 | （90） | - |
| Accumulated Installed Capacity of Solar Power | 70 | 80 | 100 | 140 | 200 | （290） | （1600） |

**Table 2-28. Directly Created Jobs of Solar PV Power Generation Industry (2005～2020) (unit: person)**

| Sector | Year | Jobs |
|---|---|---|
| Solar power generation | 2005～2010 | 12700 |
| | 2011～2020 | 37600 |

Data Source: calculated by author.

### 2.4.3 Indirect/Induced Marginal Employment Effect of Solar Power Industry

The indirect employment effect of solar power generation is mainly created in those industries strongly related with solar power production and manufacturing, solar photovoltaic cell manufacture and their upstream and downstream industries. According to indirect and induced employment coefficient we can calculate the jobs created indirectly in solar power generation industry.

**Table 2-29: Indirectly created and Induced Jobs of Solar Power Generation Industry (unit: 1000 person)**

| Sector | Year | Indirect Employment | Induced Employment | Total |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Solar PV Industry | 2005 | 11.1 | 29.4 | 40.5 |
| | 2006 | 32.9 | 89.1 | 122.0 |
| | 2007 | 74.0 | 203.3 | 277.3 |

Data Source: calculated by author.

The prices of solar cells subject to great price fluctuations, and considerable parts of China's current production is to be sold abroad, so it is difficult to predict the production and employment of solar cells for the next 10 years. Based on the prediction of China's solar PV power generation system for 2005 to 2020, we may derive the indirect and induced employment opportunities as shown in Table 2-30.

**Table 2-30 Indirect and induced employment created by PV solar power generation infrastructure investment from 2005 to 2020 (unit: person)**

| Sector | Year | Indirect Employment | Induced Employment |
|---|---|---|---|
| solar power generation infrastructure investment | 2005 | 270 | 640 |
| | 2006 | 500 | 1190 |
| | 2007 | 940 | 2220 |
| | 2008 | 1740 | 4120 |
| | 2009 | 2430 | 5750 |
| | 2010 | 3390 | 8020 |
| | 2005～2010 | 9270 | 21940 |
| | 2011～2020 | 27500 | 65000 |

Data Source: calculated by author.

### 2.4.4 Policy Recommendations of Promoting Employment with Solar Power Industry

As a rising industry in the wave of global green economy, photovoltaic industry will maintain a rapid growth rate in the future. International Energy Agency and European Photovoltaic Industry Association made positive prediction of future photovoltaic generation market- globally photovoltaic generation will account for 11% of total generation by 2020 and 20% by 2040. It’s estimated that by 2020 solar power generation installed capacity will reach 20000MW in China, and annual generation amount will account for more than 8% of all generation from primary energy. The positive development trend will help stimulate employment in the sector and increase revenue.

**(1) Further expand international and domestic photovoltaic market to expand domestic**

**employment**

Solar photovoltaic companies in China are mostly started by entrepreneurs with oversea education experience and technical expertise. As a result many of these companies have advanced technology and achieved continuous technology breakthroughs. They have developed almost 100 patented technologies. Besides, via bring in technologies, carrying out R&D, purchasing equipment from international market, these companies have developed core technology of polycrystalline silicon production technology and competitive overall capacity internationally. Some leading companies even started to set up branch companies in the U.S. to be contractors for solar power projects, such as Wuxi Shangde Co., Jiangsu Zhongneng Co., Suzhou Atesi Co., etc. The development of photovoltaic manufacture companies in China is helpful for expanding market share overseas for China and increase employment rate.

**(2) Human resource and financial investment are needed for R&D and marketing.**

With the increasing attention on low-carbon development policy in China, solar power generation has great potentials. Solar power generation companies could adopt flexible approaches to develop various feasible technologies. Due to insufficient technology R&D capacity in solar power generation market and manufacture industry in China, it is recommended that the government should provide incentive policies to encourage medium or small-sized companies to enter solar power generation market, and encourage enterprises and research institutes to cooperate on R&D in order to change the status of “market and technology are both overseas but not available domestically” and to further utilize the employment effect of solar power generation.

**(3) Provide policy support and social security for photovoltaic industry to promote development of the industry and to stimulate employment opportunities**

The global economic recession had various negative impacts on the photovoltaic industry in China. First the silicon material was influenced and price of solar cells and solar panels dropped rapidly, leading to huge losses of many companies; secondly, the freeze of capital market lead to tension on cash flow in many companies; thirdly international policy changes lead to shrinking of traditional market demand. Currently photovoltaic industry in China is faced with tremendous challenges. Competition is getting more and more intense, and integration of the industry is accelerating, indicating challenges posed by the centralization of the industry. Companies with capital, technology, brand and management advantages will become the dominant leaders in the market, while small and medium sized companies focusing on OEM or supporting services will face challenges to either transfer themselves or being phased out by the market. This requires the government to provide policy support such as tax credit for solar power generation companies, to support R&D and human resource capacity building, to provide unemployment, medical and social security systems for the labor force in the industry.

# 3 Basic Industry

## 3.1 Employment Effect of Basic Industry

Low carbon development has prominent effects on basic industry. The number of employed in the basic industry is in positive proportion to energy consumption, but in reverse proportion to output of basic industry sector. It proves that with the implementation of Energy Saving and Emission Reduction Strategy, as well as the absolute decrease in energy consumption, the number of employed in the basic industry sector is decreasing. For each 1% decrease in energy consumption in basic industry sector, the number of the employed will decrease by 1.2% (employment-energy elasticity); for each 1% increase in added value in industrial output, the number of the employed will decrease by 0.4% (employment-output elasticity). It is commonly believed that due to the employment of high efficient equipment, both the level of energy consumption and the employment will diminish to some extent. This finding is very consistent with some relevant literature.

According to the forecasts of China's economic growth in the next two years by some authoritative organizations, we compute China's GDP and the added value of different industries as shown in the following table[47]:

**Table 3-1：China's Added Values in Major Sectors from 2005-2010**

| Sector | Added Value（10 Billion RMB） | | | | | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| **Total** | 1832.17 | 2045.56 | 2283.80 | 2489.34 | 2688.49 | 290357 |
| **Primary Industry**（Farming, forestry, herding, and fishery, etc） | 224.20 | 235.41 | 257.13 | 27880 | 298.42 | 319.39 |
| **Secondary Industry** | 873.64 | 986.92 | 1110.93 | 121479 | 1314.67 | 1422.74 |
| Basic Industry | 772.30 | 871.75 | 982.66 | 1072.90 | 1160.08 | 1254.34 |
| Mining | 102.81 | 116.62 | 130.03 | 141.97 | 15350 | 16598 |
| Manufacturing | 599.05 | 687.37 | 766.37 | 836.75 | 90474 | 978.25 |

47 The GDP growth rate of 2009 and 2010 is 8%, which is based on estimates of National Information Centre and World Bank. The economic structure between the three industries is mainly based on ERI scenarios (Jiang Kejun, eta al, 2009).

| | | | | | | |
|---|---|---|---|---|---|---|
| Power, gas, and water production and supply | 67.70 | 77.36 | 86.25 | 94.17 | 101.83 | 11010 |
| Construction | 101.33 | 115.17 | 128.26 | 141.89 | 15458 | 168.40 |
| **Tertiary Industry** | 734.32 | 823.22 | 915.73 | 995.73 | 1075.39 | 1161.42 |
| Transportation, storage and postal service | 107.97 | 120.47 | 133.66 | 146.87 | 15862 | 171.31 |
| Wholesale, retail, lodging. and dining | 176.65 | 195.58 | 218.51 | 238.97 | 258.09 | 278.74 |
| Others | 449.70 | 507.16 | 563.55 | 609.88 | 658.67 | 711.37 |

Based on historical analysis, from 1985 to 2004, the energy intensity of basic industry decreased at an annual average rate of 1.91%. This rate may be taken as normally technical progress rate without implementing the ESER policy. So, the objective of 20% EI decrease from 2005 to 2010 would mean another 2.49% decrease during 2005-2010 on the BAU scenario (basic as usual). Control the projection of added value of basic industry constant[48], it would only need to consider the change rate of energy variable. Therefore, based on the 1.2% of energy elasticity of the basic industry, as well a total energy consumption reduction rate of 12.45% from 2005 to 2010 (about 198.57 million tce saving), it could be inferred that from 2005 to 2020, fulfilling the goal of ESER would cause 15.34 million employment reduction in the basic industry, means an annual average of 3.07 million jobs lost[49].

## 3.2 The Iron and Steel Industry

China now is experiencing a process of rapid urbanization. Demand for iron and steel products from industries such as construction, transportation, machinery manufacturing (and) etc. has been buoyant for long, driving the speedy development of iron and steel industry. In this context, Chinese iron and steel industry has undergone a fast growth over the past ten more years. However, due to its own manufacturing features of high energy consumption, high pollution and enormous greenhouse gas emission, the industry is one of the key sectors subject to emission reduction. China’s policies of energy conservation and emission reduction are aiming at pushing up production efficiency and efficient energy consumption of the iron and steel industry as well as

48 Here taking the hypothesis that the the output will not be dropped by ESER policy and other impulses have been considered into the projection, such as the impact of financial crisis.
49 The estimate might be compared with another similar research recently (Guo et al, 2009）, in which an employment effect impacted by international trade in 2008 have been explored. The result is that China could see a decrease of 7.93 million of direct employment in 2008 owing to the decrease of export in the same period.

curbing its overcapacity; these measures in their implementation have cast corresponding influence on employment.

### 3.2.1 The status quo and prospect of the development of iron and steel industry

As a basic industry, China's iron and steel industry has keeping a fast growing pace commensurate with the country's industrialization and urbanization. Chinese gigantic iron and steel industry produces an output accounting for 40% of the world's total, directly employing a labor force of roughly 3.58 million. The following figure demonstrates the dynamic trend of iron and steel produced and consumed in China since 1985.

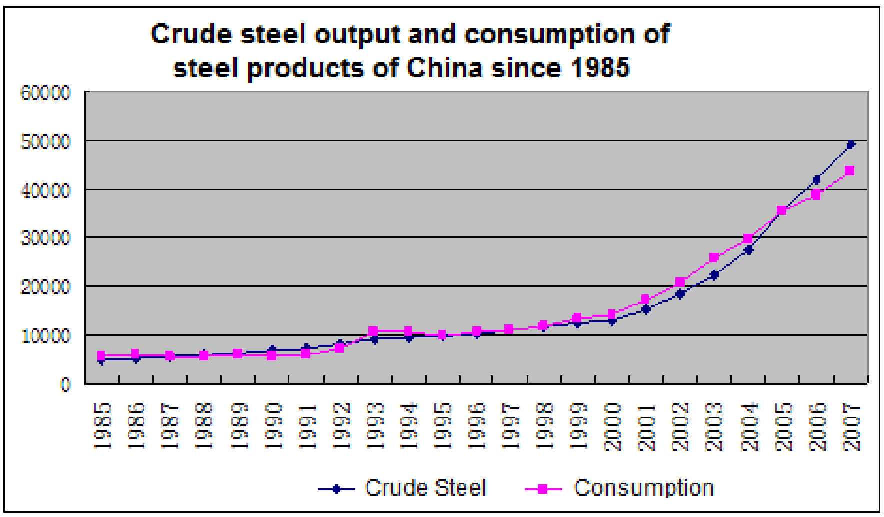


**Figure 3-1: Crude steel output and apparent consumption of steel products of China since 1985**[50]

After years of extensive development, China's iron and steel industry is now plagued by acute overcapacity, uneven maturity of manufacturing technologies and low industrial concentration, lagging still far behind developed countries. The energy consumption, main pollutants discharge and industrial added value of the iron and steel industry account for 25.1%, 10%-16% and 8.34%

[50] Source: (1) Data of crude steel output from China Steel Industry Yearbook; (2) Apparent consumption of steel products: Data 1985-2000 from Discussion on the development trend of China's steel products consumption, Wang Dingwu, World Metals, Oct 22 2002; Data 2001-2007 from The performance of China's iron and steel industry in 2007 and analysis on the demand and supply of iron and steel industry in 2008, Qi Xiangdong, No.2 2008 Metallurgy Management.

of the national total respectively, but in comparison, only 4.64% of employment nationwide can be attributable to the iron and steel industry. Therefore, we see the iron and steel industry is a sector typical of high carbon emission but low employment contribution. Table 3-2 shows us the energy consumption and $CO_2$ emission of China's iron and steel industry in recent years, from which we could see this industry is facing a tough task in terms of energy saving and emission reduction as well as mitigating climate change.

**Table3-2: Energy consumption and carbon emission of China's iron and steel industry**

| Year | Crude steel output (10,000 tons) | Energy consumption （10,000 tce） | $CO_2$ emission | Share of $CO_2$ emission in national total（%） |
|---|---|---|---|---|
| 2001 | 15163.44 | 13026.35 | 32981.8 | 10.4897 |
| 2002 | 18236.61 | 14131.19 | 35751.73 | 10.7635 |
| 2003 | 22233.60 | 17671.65 | 44709.10 | 11.4652 |
| 2004 | 27279.79 | 20556.72 | 51916.74 | 11.5859 |
| 2005 | 35323.98 | 24920.01 | 62894.77 | 12.7257 |
| 2006 | 41914.85 | 28507.87 | 71911.63 | 13.2354 |
| 2007 | 48966.00 | 32452.40 | 81780.42 | 13.9547 |

### 3.2.2 Policies responding to climate change for China's iron and steel industry

In light of the significance of iron and steel industry in national economy, multiple targeted policies and programs have been launched for the industrial development, of which energy efficiency, emission reduction and low carbon development are among the important contents. In 2005, NDRC formulated the Development Policies for Iron and Steel Industry, which directs the enterprises to build the recycling iron and steel plants by making the most effective utilization of waste gas, waste water and waste slag as well as accomplishing zero-emission as per the requirements of a recycling economy. And in 2009, the State Council promulgated the Restructuring and Revitalization Planning for Iron and Steel Industry that explicitly proposes the implementation of special projects for technical advancement and transformation of steel industry and gives top priority to the recycling economy and techniques for energy efficiency and emission reduction. The said planning defines a new energy-efficiency target for major large and medium-sized iron and steel enterprises, pursuant to which backbone iron and steel enterprises shall satisfying the following by 2011: comprehensive energy consumption per ton steel no more than 620 kg standard coal, carbon emission less than 1.8 kg, and attained targets for both pollutant emission concentration and total pollutant emission.

The energy efficiency and emission reduction for iron and steel industry focus on the phase-out of lagging capacity and the introduction of advanced technologies, of which a series of policies and measures aimed for medium and small enterprises have been implemented.

**(1) Capacity replacement**: China's capacity of crude steel hit 620 million tons in 2008, of which more than 100 million tons can be attributed to excessive capacity and are mostly produced by medium and small enterprises without comprehensive utilization facilities and with low efficiency and heavy pollution. Therefore materials and energy consumptions and pollutant emission can be effectively reduced by phasing out lagging capacity and supplementing advanced capacity.

**(2) Advanced techniques for energy efficiency and emission reduction**: multiple energy efficiency and emission reduction measures are applicable because of complicated manufacture processes and techniques adopted in iron and steel production. In general, they can be divided into three categories: namely the enhancement of utilization efficiency in energy and raw materials, the intensification of the recovery and utilization of secondary energy, and the improvement of the recovery and disposal of green house gases. In particular, for all iron and steel manufacture processes, the techniques and equipments with significant efficiency in energy-saving and emission reduction can be summarized as follows:

**Table 3-3: Techniques and equipments with significant efficiency in energy-saving and emission reduction in iron and steel industry**

| Process | Techniques or equipments | Process | Techniques or equipments |
|---|---|---|---|
| Coking | Coal moisture control equipment | Converter | Heat exchange for hot stove |
| | Coke dry quenching(CDQ) equipment | | Continuous casting equipment |
| | Heat recovery of coke-oven gas (COG) | | Sensible and latent heat recovery for Linz Donawitz Gas(LDG) |
| | The next generation coke furnace(SCOPE21) | Electric furnace | DC electrical arc furnace |
| Sintering | Boiler for heat recovery of cooler exhausts | | Scrap preheating |

<table>
<tr><td></td><td>Boiler for heat recovery of master exhaust</td><td rowspan="3">Steel rolling</td><td>Double-preheating regenerative furnace</td></tr>
<tr><td rowspan="5">Blast furnace</td><td>Top-pressure recovery turbine plant(TRT)</td><td>Hot charging and hot direct rolling</td></tr>
<tr><td>BFG Combined-cycle power generation(ccpp)</td><td>Continuous annealing equipment</td></tr>
<tr><td>Dry-type TRT</td><td rowspan="3">Others</td><td>Power generation with high efficiency(Self-powered steel plant)</td></tr>
<tr><td rowspan="2">Pulverized coal injection(PCI)</td><td>Oxygen generating plant with high efficiency</td></tr>
<tr><td>Recycling equipment for waste plastics</td></tr>
</table>

**(3) Upgrade of production techniques:** It refers to the replacement of long-process of blast furnace and converter with high energy consumption and heavy pollution by short process of electrical furnace with low energy consumption and light pollution. In fact, the energy consumption and pollution amount of these two processes mainly result from the different raw materials. Long process adopts iron ore and coal while short-process uses steel scrap. However, the application of short process still largely depends on the availability of raw materials.

At present, policies responding to climate change for China's iron and steel industry focus on capacity replacement and the application of advanced technology for energy efficiency and emission reduction. As to short process of electrical furnace, the progress has been comparatively slow due to limited steel scrap resource. In particular, capacity replacement mostly involving in shutting-down of lagging capacity under the background of excess capacity in China, with strict limitation on the increase of any advanced capacity. In 2007, NDRC successively entered into a responsibility warrant with 28 provinces, municipalities and autonomous regions with iron and steel enterprises in 2 groups, which assigned the task of phase-out of lagging capacity by 2010 to each enterprise and put the supervision responsibility upon local governments. In 2009, the Restructuring and Revitalization Planning for Steel Industry proposes a system of accountability and raise the existing phase-out standards in an effort to eliminate lagging capacity of 72 million tons in iron making and 25 million tons in steel making within 3 years.

**Table 3-4: Plan for phase-out of lagging capacity for China's iron and steel capacity (Unit: 10,000 tons)**

| year | Capacity of blast furnace | Capacity of converter | Capacity of electrical furnace |
|---|---|---|---|
| 2007 | 4,863.39 | 3,096 | 2,657.05 |
| 2008 | 615.55 | 120 | 539 |
| 2009 | 1,094.98 | 338 | 228 |
| 2010 | 2,618 | 982 | 167 |
| **Total** | **9,191.92** | **4,536** | **3,591.05** |

Source: the warrant of phase-out of lagging capacity between NDRC and governments at provincial level from NDRC website

As to phase-out of old-fashioned capacity, focusing on the technical advancement and long-term development, China's backbone iron and steel enterprises has adopted a different strategy with that of medium and small enterprises, by which only a small portion of capacity can be attributed as lagging capacity under mandatory phase-out standards while most of capacity are replaced due to technical upgrade and without any explicit administrative orders. In accordance with China Iron and Steel Year Book 2008, China's backbone iron and steel enterprises contributed 68.87% of total iron-making capacity and 73.45% of total steel-making capacity, and only 33 out of 948 iron and steel enterprises with lagging capacity are attributed to the said backbone enterprises while the remaining 915 enterprises are largely medium and small enterprises. Therefore the lagging capacity from small enterprises needs to be phased out, including 45.4692 million tons of iron-making capacity and 48.3855 tons of steel-making capacity, respectively.

### 3.2.3 The Impact of Low Carbon Development on Employment in Iron and Steel Industry

The impacts of low carbon development on employment in iron and steel industry basically include job losses due to phasing out of lagging production capacities and new jobs created due to adoption of energy-saving and emission-reduction technologies.

**(1) Job losses due to phasing out lagging production capacity**

- **Impact of phasing out lagging iron-making production capacity**

As per letters of commitment signed between the National Development Commission and 30 provinces, municipalities and autonomous regions, a total production capacity of 91.9192 million tons is to be closed down by the end of 2010 involving 952 blast furnaces from 948 companies.

Based on our surveys with a number of iron & steel companies, an average of around 195 jobs will be lost when a blast furnace is closed down. If each province and municipality fulfills their commitment of capacity reduction, a total of around 195×952=185640 jobs will be lost.

According to the Restructuring and Revitalization Planning for Iron and Steel Industry, by the end of 2011 a further total of around 75 million tons of production capacity will be eliminated due to abandoning of blast furnaces of less than 400 cubic meters. As figures indicate in the letter of commitment, there are totally 56 blast furnaces of 300-450 cubic meters involving a production capacity of 23.412 million tons, therefore a capacity reduction of 75 million tons involves 180 blast furnaces which will cause a loss of around 35100 jobs.

- **Impact of phasing out lagging steel-making production facility**

As per the letters of commitment, by the end of 2010 a total production capacity of 81.2705 million tons will be eliminated involving 122 converters and 701 electric furnaces. According to our surveys, on average each converter requires around 324 workers and each electric furnace requires 218 workers. Therefore, the end of 2010 will see a loss of 324×122=39528 converter jobs and 218×701=152818 electric furnace jobs when the commitments are fulfilled.

According to the Restructuring and Revitalization Planning for Iron and Steel Industry, by the end of 2011 another total of around 25 million tons of production capacity will be eliminated due to abandoning of converters and electric furnaces of below 30 cubic tons. If all capacity to be eliminated was that of converters, then 44 converters need to be abandoned which may cause a loss of 14256 jobs; if all capacity to be eliminated was that of electric furnaces, around 196 electric furnaces will have to be abandoned which may cause a loss of 42728 jobs. In practice, both some converters and electric furnaces need to be closed down and 2000-30000 jobs are expected to be lost.

The following table is a summary of job losses due to capacity reduction in recent for coming years.

**Table 3-5：Employment effect in Steel and Iron Industry**

| year | Actions to reduce capacity | Job losses (1000 | Annually |
|---|---|---|---|

| | | jobs) | average loss (1000 jobs) |
|---|---|---|---|
| 2007-2010 | capacity reduction as per letters of commitment | 185.6 | 46.4 |
| 2007-2010 | capacity reduction as per letters of commitment | 152.8 | 38.2 |
| 2009-2011 | further reduction of capacity as per Restructuring and Revitalization Planning for Iron and Steel Industry | 35.100 | 11.7 |
| 2009-2011 | further reduction of capacity as per Restructuring and Revitalization Planning for Iron and Steel Industry | 20-30 | 6.7-10 |
| **total** | | **393.6-403.6** | **-** |

**(2) Impact on employment due to adoption of energy-saving and emission reduction advanced technologies**

Theoretically speaking, the adoption of energy-saving and emission reduction technologies will help create new jobs. For example, the use of sintering gas desulphurization technology, which recycles gases formerly directly discharged, requires new operational procedures, new functions and new jobs. Some other advanced technologies may cause replacement of new jobs for old jobs. For example, the use of dry coke quenching technology causes new jobs associated with this new technique and jobs losses associated with the original wet coke quenching. Generally speaking, the full use of existing energy-saving and emission reduction technologies will not only help reduce energy consumption, decrease discharge of greenhouse gases and pollutants and effectively recycle secondary energy, but also create many new jobs thus easing the pressure from job losses due to technological advancements.

Unfortunately, due to limited sources it has been difficult to find data that accurately reflects the impacts on employment of energy-saving and emission-reduction technologies, and only a roughly extrapolated calculation can be provided.

- **Impact on employment due to adoption of dry coke quenching technology**

Based on data from Monitoring Center of China Labor Market Information Network, up to the end of 2007 there were 50,000 people employed in dry coke quenching operation, when dry coke quenching capacity accounted for 1/3 of China's total coke production. Given the current coke production capacity, if all production plants use dry coke quenching the number of employees associated with this would be 150,000 people.

The traditional wet coke quenching is just one procedure of coke production and it is difficult to obtain the accurate number of employees required. And in general, dry coke quenching requires additional equipments and procedures which produces a positive impact on employment. Additionally, the adoption of dry coke quenching technology will help increase indirect employment associated with equipment manufacturing, installation and construction, etc.

- **Impact of other energy-saving and emission-reduction technologies**

From data we have accessed relating to other energy-saving and emission-reduction technologies, only some rough employment data from individual enterprises is available, it was difficult to find employment data, especially summary data, relating to a specific technology. Given great divergence in level of technology and skills among enterprises (eg. As for sintering gas desulphurization, five approaches are in use among Chinese enterprises ), greatly varied are the mode of investment, workmanship, job arrangement and final results, therefore data from individual enterprise is hardly applicable for other enterprises. Given the current scale of China's iron & steel industry, the adoption and popularization of such technologies will help create not less than 200,000 direction jobs.

However, from a long-term perspective, the iron & steel industry is not labor intensive in nature. Even if the scale of production remains unchanged, continual technological progress, replacement of advance facilities for lagging facilities and development of automation will help increase productivity and hence cause loss of jobs. Even energy-saving and emission-reduction technologies are continually progressing which lead to higher productivity, and the positive impact on employment will diminish when such technologies are maturing.

At present, in advance countries nature resources based technologies are maturing, and the stock of steel materials has accumulated to an extent that provide basic conditions for steel scrap based production. Therefore in these countries efforts on energy-saving and emission-reduction basically focus on short process replacing long processes where the increased recycling of steel scrap not only have promote energy efficiency and emission reduction but also create many recycling-related jobs. Given China's short history of industrialization and urbanization and limited stock of steel materials, the above-mentioned work is going slowly which is therefore not covered in this report. However, with the accumulation of stock of steel materials in China it will be an inevitable trend for China to pursue energy efficiency and low carbon development by this approach.

### 3.2.4 Policy Recommendations

**1. Adjust policies and measures that eliminate backward production capacity in a proper way.**

On the whole, eliminating lagging production capacity is the correct approach, which serves not only for the low carbon development of the iron and steel industry but also for maintaining a proper total production capacity. But some specific measures still need adjustment. We should give lagging production capacity a precise definition and determine the exact production capacities that need to be eliminated. Meanwhile, we should change our previous method in which elimination can only be carried out upon executive and administrative orders. On the contrary, we should fully utilize market forces, bring to full play the role of market in which market itself lets the efficient survive and prosper while the inefficient perish. For example, improve the production costs of lagging production capacity by setting up certain policies; give certain preferences to those production modes which support green development.

**2. Complete the withdrawal mechanisms for lagging production capacities.**

Some lagging production capacities are hard to eliminate, not because the production costs are low, but because the withdrawal costs are higher than the production costs. In order to encourage enterprises to eliminate lagging production capacity, proper withdrawal mechanisms need to be set up. For example, give certain rewards and subsidies, provide employment opportunities of a certain proportion to workers laid off due to the withdrawal, and effectively reduce the withdrawal costs. All these measures are helpful to eliminate lagging production capacity in a timely manner.

**3. Further popularize the use of energy conservation and emission reduction technologies.**

From a long-term perspective, achieving low carbon development of the iron and steel industry is in line with the goal of maintaining healthy development of the enterprises. Its social influence is also significant. However, in the short run, the adoption of some technologies will cause a temporary increase in enterprises' production costs, which may be beyond the means of some small enterprises, thus impeding the popularization of such technologies. Maybe the best solution is for the government to provide appropriate subsidies for the adoption of such technologies and give equal treatment to all enterprises regardless of their size, thus ensuring long-term development of the entire industry at the expense of increasing short-term costs, and generating more social benefits.

**4. Steadily develop the production technique for short process electric steel-making.**

With the growing maturity of the development of China's iron and steel industry and an increasing steel inventory, the steel storage will finally reach its maximum capacity and steel scrap resources will keep increasing. We should attach high importance to this trend, and develop the technique of electric steel-making in a stable and timely manner, which is conducive to energy conservation and reduction of greenhouse gases and pollutants, and will make great contributions to employment as well.

**5. Pay due attention to employment. For iron and steel enterprises, expanding employment is not their development goal.**

We shouldn't affect the normal development of the industry by overemphasizing the importance of employment. But during the industry's development, it is possible to pay proper attention to employment while at certain stages introducing production methods that can secure enterprises' development, minimize employment losses and increase employment. For example, at present, we can slightly increase employment by popularizing energy conservation and emission reduction technologies. With the growing maturity of the industry, we can create new jobs by improving techniques and technologies and increasing the recycling of steel scrap, while at the same time, we shall pay proper care and attention to those employees who face layoff, make proper arrangements for those laid-off workers and minimize their losses.

# 4 Green Investment

Starting from 2008, China's total export witnessed a steep slump because of the global financial crisis, which imposed a great impact on Chinese macro-economy. Due to decline in both imports and exports, a significant unemployment trend occurred in the coastal regions where the export-oriented economy dominated. Many other domestic industries are also affected by this negative impact. To alleviate this trend, Chinese government issued a 4 trillion yuan economic stimulus plan. This plan aims to sustain economic growth, adjusting the economic structure, expanding domestic demand and improving household well-beings by increasing government investment. After the implementation of this plan, major economic indicators steadily returned back to a healthy level. To some extent, this plan alleviates the crisis in front of China. However, many scholars have evaluated the concrete measures and they think China has not yet returned back to employment –led economic recovery phase.

Different investment structure will incur different job creation effects. Based on the fact that main investment flow into infrastructure sectors in order to maintain economic growth rate, the plan neglect the positive influence of employment to expanding domestic demand and maintaining social stability. "2009 Green book of Population and Labor" designs a plan for the 4 trillion investment package which gives employment creation more priority. By this plan, 60% investment should flow into education, health and care, social security and residential service or related sectors. In fact, in addition to the important employment goal, China's economic stimulus package would also contribute to low carbon development. Until now, not so many scholars have done some in-depth analysis and research in this area. This sector will examine the economic stimulus and job creation effect brought about by the "4 trillion" economic stimulus plan. Our research will mainly focus on the green investment aiming to promote low-carbon development and ecological environmental protection based on data issued by NDRC.

## 4.1 Identifying Green Investment and Green Industries in China's Economic Recovery Plan

According to the data published by the State Development and Reform Committee, the Chinese government made some revisions to the original investment program. For details, please refer to Table 4-1. After these revisions, about 210 billion yuan was channeled into energy-saving and emission-reducing initiatives and ecosystem enhancement scheme. Among these investments, the infrastructure industry undoubtedly took the lion's share, taking up about 1,500 billion yuan. The post-quake reconstruction in Sichuan took up about 1,000 billion yuan. In addition, 400 billion yuan was invested in the affordable housing project. For safety reasons, more energy-saving and environment-friendly materials would be used. An extra 3,700 billion yuan would be invested in the people's livelihood project for the purpose of improving the rural people's living standards in a sustainable and environment-friendly way. The adjustment of industrial structure and technological innovation would roughly take up 370 billion yuan. In the field of education, public health, cultural projects, family planning, etc. 150 billion yuan would be needed. Based on these figures, we are confident to draw a conclusion that quite a number of investments fell into the category of environment-friendly investment.

Among the miscellaneous assortment of investments, the energy-saving and emission-reducing initiatives, ecosystem projects, which bore much relation to climate change, absorbed 580 billion yuan, taking up 14.5% of the total investment. So far, among the approved amount of investment, 10% had been invested in energy-saving and emission-reducing initiatives, ecosystem enhancement and environmental protection. To achieve a better understanding of the positive impact of the 4,000 billion investment program on the development of low-carbon economy and the government's job creation endeavor, this current research seeks to explore the differential contribution of different kinds of investments to job creation(see table 4-1).

**Table 4-1 Components of 4,000 Billion Investment Program and Proportion of "Green Investment"**

| Projects of Investment | Pre-adjustment (Unit: 100 million) | Post-adjustment (Unit: 100 million) | Investment Related to "Green Investment" | Proportion of "Green Investment"(%) |
|---|---|---|---|---|
| Infrastructure (Railway, Highway, Airport Construction, Power Grid) | 18000 | 15000 | ? | ? |

| | | | | |
|---|---|---|---|---|
| Affordable Housing | 2800 | 4000 | Investment in Energy-Saving and Environmental Protection | ? |
| Rural Livelihood Project Construction | 3700 | 3700 | Rural Environmental Infrastructure Facilities | ? |
| Adjustment of Industrial Structure and Technological Innovation [51] | 1600 | 3700 | Optimization of Industrial Structure, Environmental Protection Technology, Energy-saving Projects | 100% |
| Energy-saving and Emission-reducing and Ecosystem Project Construction | 3500 | 2100 | Energy-saving and Emission-reducing and Ecosystem Project Construction | 100% |
| Post-quake Reconstruction [52] | 10000 | 10000 | Low-carbon Building Construction, Public Transport, Low-carbon Urban Planning, etc. | ? |
| Education, Public Health, Cultural Projects and Public Services | 400 | 1500 | Popularization of Science and Technology | ? |
| **Total** | **40000** | **40000** | | **?** |

Source: State Development and Reform Committee, CEIC;

Note: The symbol "?" denote the number is still uncertain.

Based on the data in Table 4-1, we can find that in addition to some investments specifically designed for environmental protection purposes and climate change, a majority of investment programs could possibly cut across environmental protection, energy-saving and low carbon economy. So far, we still do not have the specific data to support this argument. For instance, the investment in infrastructure and housing could possibly involve some investment in new construction materials, which might positively impact on the low-carbon industries. The investment in the post-quake reconstruction and the rural livelihood projects may involve some investments in low-carbon economy as well. Due to the lack of specific data in current research, we choose not to include these investment items in this research. Besides, one important item in

[51] The original version is "Investment Based on Independent Technological Innovation and Industrial Structural Adjustment".

[52] Currently, CASS is responsibl for the construction of a low-carbon project in the earthquake-struck Guangyuan, Sichuan Province. According to our study, we found that the post-quake reconstruction, so far, had not taken the low-carbon concept or low-carbon technology into consideration, neither did the reconstruction would relate to the construction industry, urban planning or project introduction. Guangyuan was the first administrative unit to apply for reconstruction by using low-carbon technology. Guangyuan is now considering urban planning by using low-carbon technology. By taking on the advantage of reconstruction, Guangyuan plans to lead its economic growth onto the path of economic growth by low-carbon.

rural livelihood project is the construction of biogas digesters in rural areas. Based on current data, we define the investment to construct "biogas digesters of 2.47 million households" as green investment. According to "National Rural Biogas Construction Investment Planning", the average investment per household is about 3041 yuan. Thus, the total investment is about 7.511 billion yuan, accounting for 2% of the total investment for rural livelihood project construction. This investment will create 197.6 thousand direct rural jobs (800 jobs are created for the construction and maintenance of 10000 digesters). If we assume that there are 5% of investments in livelihood project construction are green investment and all of them will flow into biogas digesters project, the green investment in livelihood project construction is estimated about 18.5 billion yuan. So, the current research focuses on the following three issues（1）the investment in energy-saving and emission-reducing as welll as ecosystem enhancement;（2） the adjustment of industrial structure and technological innovation；（3）biogas digesters investment projects in rural areas.

## 4.2 Directions of the Flow of Investments

This research seeks to predict the "green investment"-induced impact on job creation by measuring the input-output ratio. Therefore, we need to examine closely the specific proportion of "green investment" in respective industry. Our analysis is as follows:

- **Investment in Energy-saving and Ecosystem Enhancement Program**

About 230 billion Yuan was approved by the State Council in the Fourth Quarter of 2008. About 23 billion Yuan, 10% of the approved investment, was scheduled to be invested in energy-saving and emission-reducing as well as environmental protection. About 13 billion yuan was aimed at urban construction, sewage treatment as well as sewerage upgrade. Four billion yuan would be invested in controlling pollution in some key areas like the Huaihe valley, Songhuajiang River valley and Danjiangkou Reservoir area. Specifically, the four billion investment was aimed at increasing the water and waste treatment capability. Another 3.5 billion yuan was invested in the protection of natural forests and key shelterbelts.[53] Quite obviously, China's energy-saving and emission-reducing initiative as well as ecosystem enhancement should take place in the

[53] http://www.sougang.com/H6.aspx?F=/Funny/Admin/View.P6&ID=26949&T=N.

construction industry, equipment manufacturing, agriculture (forestry), hydraulic engineering, environment as well as public service management. Taking one of China's hydraulic project as an example, we found that the construction fee, procurement price as well as the installation fee took up 60%, 30% and 10% respectively. To achieve a better understanding of differential contribution to economic growth, we will do a further analysis of the impact caused by energy-saving and emission-reducing, ecosystem enhancement as well as environmental protection.[54]

- **Investment in the Adjustment of Industrial Structure and Technological Innovation**

The development of low-carbon economy dictates that a predominant amount of environmental protection investment should go to the adjustment of industrial structure and technological innovation. As for the adjustment of industrial structure, the Chinese government focused primarily on how to curb the excessive industrial production and increase the proportion of the tertiary industry and employment rate in this particular sector of economy. In doing so, the government hoped to reduce its excessive reliance on the development of heavy industry for economic growth and improve the productivity on every unit of carbon consumption. As for the technological innovation, the government hoped to promote the development of low-carbon economy by means of developing new energy technologies, emission-reducing technology like wind power, solar power, biomass and bio-energy as well as carbon capture technology, etc. The government has also made a meaningful effort to promote the efficient use of energy and develop new energy-saving products and technologies. The present tendency suggests that the investment in the adjustment of industrial structure and technological innovation should go to some energy-consuming industries as well as the R & D. As the Reinvigoration Scheme for Key Industries launched by the Coordination Services of the State Development and Reform Committee and the Ministry of Industry & Information pointed, the major purpose of the 4,000 billion investment program was aimed at reinvigorate some traditional key industries like steel, auto industry, shipping building, petrochemical industry, some light industries, textiles, non-ferrous metal industry, equipment manufacturing, logistics industry as well as information industry. However, due to the lack of necessary data, we failed to provide a detailed analysis in

[54] Guo Ju'er, et al, Predictions of the Impacts of 4,000 Billion Investment on China's Economic Growth.

regard to each specific amount of investment.

As the adjustment of industrial structure and technological innovation may cut across a wide range of industries, the direction of the flow of investment is thus hard to pin down. For ease of analysis and estimation, we approach this topic by analyzing the adjustment of the three major sectors of economy. We made some revisions to the input-output table, which makes it easier for us to estimate the job creation effects as a result of the investment in industrial structural readjustment. The employment coefficients in the three sectors of economy are as follows (table 4-2). If there are two possibilities regarding the investment in the structural readjustment and technological innovation: the economic increase based on output—about 80% of investment goes to the secondary sector of economy and the rest 20% of investment goes to the tertiary sector of economy; and the economic increase based on job creation—about 60% of investment goes to the secondary sector of economy and about 40% goes to the tertiary sector of economy.

**Table 4-2 Investment in Three Sectors of Economy and Impact**

| Sectors of Economy | Output Coefficient | Impact Factor | Labor Coefficient | Impact Factor Based on Indirectly-Created Employment | Coefficient Impacting Employment |
|---|---|---|---|---|---|
| The Primary Sector | 2.167 | 0.812 | 0.0113 | 0.0071 | 0.0140 |
| The Secondary Sector | 3.369 | 1.262 | 0.0138 | 0.0134 | 0.0300 |
| The Tertiary Sector | 2.470 | 0.926 | 0.0414 | 0.0121 | 0.0186 |

The strength of this type of analysis lies in the policy implications. That is to say, due to the different objectives set by decision-makers, the output-based “green-investment” and job creation-based “green investment” will inevitably lead to different economic results.

- **Rural Livelihood Project Construction**

According to “National Rural Biogas Construction Plan”, from 2006 to 2010 Chinese government will help to construct biogas digesters for 13.175 million households. The total investment will amount to 40.65 billion Yuan, which means 8 billion Yuan investment per year. The number is rather close to our estimation of investment for biogas digesters construction in economic stimulus plan. According to the “Regulation rule for construction bond of rural biogas digesters project”, the volume per biogas digesters is about 8 cubic meters. We may derive the related investment to specific sectors based on the “one pool of three improvements” project[55]. (See figure 4-3)

**Table 4-3：The Composition of Rural Biogas Digesters Construction and Maintenance Cost**

| Input | Items of Expenditure | Percentage of Total Input % | Related Pure Sector |
|---|---|---|---|
| Construction Cost | Cement，sand & stone，red brick | 52.6% | Non-metal Mineral Products |
| | Steel | 3.2% | Metal Smelting and pressing |
| | Mechanic | 5.3% | Comprehensive technical service industry |
| | General Worker | 10.5% | Construction |
| | Methane Equipment and Components | 12.6% | Electronics, Machinery and Equipment manufacturing |
| Maintenance Cost | Maintenance Worker | 15.8% | Residential service and other services |

## 4.3 Analysis of the “Green Investment” Induced Employment

Based on the previous analysis, we did a further analysis by examining the specific allocation of “green investment” to each industry. See Table 4-4 below.

**Table 4-4 Allocations of the “Green Investments” to Pure Sectors**

| Project Category | Volume (Unit: 100 million) | Corresponding Industries |
|---|---|---|
| Energy-saving and Emission-reducing and Ecosystem Enhancement Program | 2100 | 60% for construction industry; 15% for general-purpose and specific- purpose equipment manufacturing; 15% for electrical industry and industrial machinery; 10% for hydraulic project, environmental project as well as public service management |

[55] The basic requirement of “one pool with three improvements”: (1) methane-generation pits of about 8 cubic meters; （2） changing lap; (3) changing lavatories; (4) changing kitchen. See “Regulation rule for construction bond of rural biogas digesters project” (draft).

| | | |
|---|---|---|
| Industrial Structural Adjustment and Technological Innovation | 3700 | 70% for Secondary Sector and 30% for the Tertiary Sector |
| Rural Livelihood Project Construction （Biogas Digesters Project） | 185 | 52.6% for Non-metal Mineral Products； 3.2% for Metal Smelting and pressing；12.6% Electronics, Machinery and Equipment manufacturing； 10.5% for Construction; 5.3% Comprehensive technical service industry; 15.8% Residential service and other services |

Based on the input-output table, we can compute the output multiplier, labor coefficient, indirectly-created employment impact coefficient as well as coefficient impacting employment rate. By using this method, we can precisely measure the effects associated with the "green investment" in some booming industries. It is predicted that the investment in energy-saving and emission-reducing programs could generate roughly about 698.15 billion Yuan. The investment in structural adjustment and technological innovation, in the context of economic growth based on output and employment, could possibly generate about 1179.91 billion Yuan and 1113.42 billion Yuan respectively. The investment in Biogas Digesters Project of rural livelihood construction could generate about 59.03 billion Yuan. The employment impact arising from the increase in output is as follows:

### 4.3.1 Energy-saving and Ecosystem Enhancement and Impact on Employment

By computing the coefficient impacting employment, we could well predict the exact impact on employment rate as a result of the government's energy-saving and emission-reducing initiatives. For details, please refer to Table 4-5. As a prediction, this research believes that China's economic revival program, the energy-saving and emission-reducing initiatives to be exact, could generate about 567,000 jobs in some high-polluting industries. In the meantime, the energy-saving and emission-reducing initiatives could create about 1.29 million jobs China's industries in general.

**Table 4-5: Energy-saving and Ecosystem Enhancement and Impact on Employment (10000 people)**

| Industries | Directly Effect | Indirect Effect | Induced Effect |
|---|---|---|---|
| Construction | 29.2 | 13.3 | 72.4 |

| | | | |
|---|---|---|---|
| General-purpose, Special-purpose Equipment Manufacturing | 4.5 | 3.4 | 15.8 |
| Electrical Industry and Industrial Machinery | 3.2 | 3.1 | 14.9 |
| Hydraulic Project, Environment and Public Service Management | 19.8 | 2.6 | 26.2 |
| **Total** | **56.7** | **22.4** | **129.3** |

### 4.3.2 Industrial Structural Adjustment and Technological Innovation and Impact on Employment

Based on the analysis of hypothetical policies, we are confident to predict that the output-based economic growth may well create about 409,000 job opportunities for the secondary sector of economy and 307,000 job opportunities for the tertiary sector of economy, about 716,000 job opportunities in total. The indirectly-created jobs total 486,000. As a result, the increased job opportunities caused by industrial expansion could reach 2.23 million. For the employment-led scenario， the directly-created job opportunities due to industrial expansion will be about 920,000 while the indirectly-created job opportunities will be about 477,000, the total employment increased is about 2.34 million if combined. The figures are shown in the following table (table 4-6).

**Table 4-6 Industrial Structural Adjustment and Technological Innovation and Impact on Employment**

| Relevant Policies in Hypothetical Situations | Directly-Created Employment | Indirect-Created Employment | Coefficient Impacting Employment |
|---|---|---|---|
| **Economic Growth Based on Output (output effect: 1179.91 billion Yuan)** | | | |
| The Secondary Sector | 40.9 | 39.6 | 88.8 |
| The Tertiary Sector | 30.7 | 9.0 | 13.7 |
| **Total** | **71.6** | **48.6** | **102.6** |
| **Economic Growth Based on Employment(output effect: 1113.42 billion Yuan)** | | | |

| | | | |
|---|---|---|---|
| The Secondary Sector | 30.7 | 29.7 | 66.6 |
| The Tertiary Sector | 61.3 | 18.0 | 27.6 |
| **Total** | **92.0** | **47.7** | **94.2** |

### 4.3.3 Rural Livelihood Project Construction（Biogas Digesters Project）

We may derive detailed employment effects of biogas digesters project of different sectors based on the employment coefficient calculated (see table 4-7).

**Table 4-7：The Employment Effects of Rural Biogas Digesters Construction Investment (unit: 10000 people）**

| Sector | Direct Employment | Indirect Employment | Induced Employment |
|---|---|---|---|
| Construction | 0.45 | 0.20 | 0.46 |
| Non-metal Mineral Products | 1.31 | 1.16 | 2.35 |
| Electronics, Machinery and Equipment manufacturing | 0.24 | 0.23 | 0.64 |
| Metal Smelting and pressing | 0.05 | 0.06 | 0.15 |
| Comprehensive technical service industry | 0.34 | 0.15 | 0.20 |
| Residential service and other services | 0.24 | 0.28 | 0.49 |
| **Total** | **2.63** | **2.07** | **4.29** |

### 4.3.4 Conclusions

Based on the calculation results above, green investment will create about 4.40 ～4.51 million job opportunities for China. A total of 2.08 million jobs are created by energy-saving and ecosystem enhancement investment; another 2.34 million jobs can be generated by industrial structural adjustment and technological innovation investment (based on employment-led scenario data); the construction of Biogas Digesters in rural areas can create about 90000 related job opportunities.

According to international experience, green investment should focus on improving the technological innovation capability of enterprises and cultivating markets. For the industrial structural adjustment and technological innovation investment, we assume there are 2 scenarios, the economic increase based on output and the economic increase based on job creation. The total job opportunities created by these 2 scenarios are 2.39 million and 2.23 respectively. Despite the slight decline in output, the employment-led scenario has a more significant contribution to employment promotion. Thus, industrial structure adjustment investment should focus on the flow of investment to research and development and technical services within the tertiary industry, in order to promote low-carbon technologies to develop in the long run and improve enterprises' independent R & D and innovation capability.  Based on these，China can achieve good low-carbon development and increase the level of output of a low-carbon economy.

# PART III. CONCLUSION AND RECOMMENDATION

# 1 Conclusion

Low carbon development, through affecting the capital flow, can exert different impacts over sectors in terms of output and employment. According to the study, the employment effect of a certain sector usually contains three different kinds of expressions: **direct employment effect** which is defined as jobs created in such sector to expand manufacturing when output increases; **indirect employment effect** which is defined as jobs incurred by the production of inputs to the specific sector in its production process; and **induced employment effect** which refers to the sum of all other jobs created during the production expansion. The sum of these three employment effects is the **total employment effect**.

Based on the literature reviews, investigations from companies and the analysis of inputs and outputs, this study has differentiated all the jobs created by the low carbon development policy in China's major industries. The result indicates that there are great differences in the industries of forestry, power and steel & iron because the direction of the low-carbon policy may vary greatly in different sectors. Specifically, the final result is presented as follows:

**Figure 4-8: Employment Effects in the Major Industries (Unit: 10,000 persons)**

| Industry | Sub-sector | Direct Employment Effect | | Indirect and Induced Employment Effect | |
|---|---|---|---|---|---|
| | | 2005-2008 | 2009-2020 | 2005-2008 | 2009-2020 |
| Forestry | Afforestation and Reafforestation | 577 | 183 | 841.6 | 266.9 |
| | Sustainable Forest Management | 8.93-11.16 | 7.76-9.70 | 2.89-3.61 | 2.51-3.14 |
| | Forest Tourism | 46.6 | 268.8 | 53.3 | 308.3 |
| Power Industry | Thermal Power | -5.973 | -17.025 | 34.52 | 43.73 |
| | Wind Power | 6.26-9.03 | 43.79-64.42 | 18.22-26.07 | 124.29-180.55 |

| | | | | | |
|---|---|---|---|---|---|
| | Solar Power | 13.8<br>（2005-2007） | 4.55<br>（2008-2020）[56] | 44.56<br>（2005-2007） | 17.8 |
| Basic Industry | Steel and Iron Industry | -23.15 | -1.71<br>(2009-2011) | - | - |

Obviously, the forestry industry, a typical green industry, has a huge potential to tap in low carbon employment. Jobs created as a result not only illustrate its direct effect, but also its indirect and induced effects. Within the power industry, a large number of jobs will be cut in the traditional thermal power sector because of the national policy of energy conservation and emissions reduction in the long run; while in the sectors of wind power and solar power, things are quite different. Thanks to the growing need of the clean power energy in advancing the social and economic development, the perspective of the two sectors is presented a rosy picture. In particular, due to the indirect and induced employment effect, a series of output expansion effects and employment promotions will thus be brought about in the upstream and downstream of their industrial chains. In the steel and iron industry, no new jobs are created in general. Reasons for this should be attributed to its surplus production capacity and backward technology which have to be upgraded.

In addition, the Chinese Government has unveiled a 4 trillion Yuan economic stimulus plan, which contains some investments in the fields where environmental-friendly concepts are advocated just like those low carbon sectors. Through careful differentiation, the potential employment effect of these green investments can be presented as follows:

**Figure 4-9: Employment Effect of the Green Investments (Unit: 10,000 persons)**

| Green Investment | Total Investment (100 mil. Yuan) | Direct Employment | Indirect Employment | Induced Employment |
|---|---|---|---|---|
| Energy Saving, Emissions Reduction and Bio-construction | 2100 | 56.7 | 22.4 | 129.3 |
| Structural Readjustment & | 3700 | 92.0 | 47.7 | 94.2 |

[56] 对未来进行预测时只考虑了太阳能发电产业中的光伏发电系统部门的未来直接就业趋势（间接+引致与之相同）。

| | | | | |
|---|---|---|---|---|
| Technological Renovation | | | | |
| Projects concerning<br>the Well-being of Rural Residents | 185 | 2.63 | 2.07 | 4.29 |
| **Total** | **5985** | **151.3** | **72.2** | **227.8** |

According to the data mentioned above, the green investment, about 15.0 percent of the 4 trillion Yuan stimulus package, can bring about a total of 4.5 million new jobs for the society. This demonstrates that, amid the global financial crisis, the environment-friendly investment constitutes a boon for the low carbon development and at the same time, such a move can also help boost the economic development and create more job opportunities.

# 2 Policy Recommendation

Since the reform and opening up program was introduced in late 1978, China's employment has continued to expand. By 2008, the employed population in the urban areas hit 302.1 million. The employment proportion of the primary industry went down slightly and the employment proportions of the secondary and tertiary industries both rose, with that of the tertiary industry continuously being optimized. In 2002, the Chinese Government began to carry out a proactive employment policy in order to ease the employment pressure resulting from those entering the labor market for the first time and the laid-off ones, help the surplus rural labors find jobs in towns and cities, and adjust and optimize the employment structure.

On the basis of the employment policy of "workers finding their own jobs, employment through market regulation and employment promoted by the government", efforts have been made to formulate and promulgate a number of relevant laws and regulations, such as the Employment Promotion Law, the Labor Contract Law, the Regulations on Employment Service and Employment Management and the Labor Dispute Mediation Law, to protect the legitimate rights and interests of the labors. Moreover, hard work has also been done to establish and improve the employment service and security system, strengthen the management of human resource market and professional skill training of the work force, actively promote the development of the labor market in a sound way and create a favorable institutional environment for the small and medium-sized enterprises and the individuals who want to start their own business.

Since 2008, to cope with the climate change and economic slump across the world, China has actively promoted the low carbon development and stepped up its efforts to save energy and reduce greenhouse gas emissions. The result is positive. In September 2009, leaders of all nations came together in the U.S. to attend the UN Summit on Climate Change. Chinese president Hu Jintao delivered a speech titled "Working together to Address the Climate Change Challenge". According to Hu, China will further integrate its actions on climate change into its economic and social development tasks and take the following forceful measures: first, efforts will be intensified to conserve energy and improve energy efficiency and to cut carbon dioxide emissions per unit of GDP by a notable margin by 2020 from the 2005 level; second, efforts will be made to vigorously develop renewable energy and nuclear energy and increase the share of non-fossil fuels in primary energy consumption to around 15 percent by 2020; third, much work will be done to energetically increase forest carbon sinks and increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels; and fourth, efforts will be stepped up to develop green economy, low carbon economy and circular economy and enhance research, development and dissemination of climate-friendly technologies. These measures fully exhibit China's policy direction of developing low economy in the future. Meanwhile, they will surely produce an obvious and profound impact over the employment in the relevant industries.

Energy conservancy, emission reduction and ecological environment development are the major ways of promoting low-carbon development in China. Although energy conservancy and emission reduction have negative impact on employment in industries related to fossil energy, the technology advancement and cost reduction brought about by energy conservancy and emission reduction may contribute to the long term development of the economic system. Ecological environment development has positive impact on employment in forestry sectors, including forestation, reforestation, ecological system management in forestry, forest tourism and so on.

In order to promote low-carbon development and achieve the low-carbon employment target, following suggestions are made based on the conclusion of this report:

**Low-carbon development is able to give a boost to low-carbon employment**: different industry's contribution on employment and output is varied. Generally speaking, the indirect effect of low-carbon development is more obvious than its direct employment effect. So the great potential in low-carbon employment can be tapped by adopting low-carbon development policies such as energy conservancy, emission reduction, eco-development and optimization of industry structure.

**Low-carbon service industry can be exploited to optimize the industry structure:** considering the dependency on energy of different industries and the upgrading of industry structure, China should step up developing tertiary industry, especially the one that offers R&D support to the industry like manufacturing and consumption service industry that boosts domestic demand. In the meantime, the high added-value first industry (e.g. eco-agriculture, energy cropping forestry, eco-forestry, etc.) should also be encouraged to develop to achieve the dual target of employment and low-carbon economy.

**Green investment should be expanded for more job opportunities**: the 4-trillion stimulus package is relieving the pressure facing China's economy, but China has not entered into economic recovery marked by growth of employment as most investment flows into infrastructure projects, such as transportation, construction, etc. Once "Carbon Lock-in" takes effect, the potential of emission reduction will be compromised. At present, the investment in the green industry that is associated with low-carbon development in the 4-trillion stimulus package only accounts for 1/5. We need to increase the proportion of investment in the green industry and build up a structure that puts employment first so as to set a solid foundation for a structure-optimized low-carbon economy.

**Some pilot programs can be carried out to promote low-carbon employment first in some regions and then extended to other areas**: promoting low-carbon employment needs to take into account the specific conditions in different industries and regions, and it also requires the support of policies. Given that low-carbon economy is a new model of economic development, we do not have much precedent experience to learn from other countries. Therefore, we suggest that we carry out pilot programs in some regions and in some representative enterprises/industries based on related studies. With that experience, supporting policies of low-carbon employment can be formulated.

# Annex 1: Abbreviation

CCFG: Cropland Conversion to Forest & Grassland

CDM: Clean Development Mechanism

CERs : Certified Emissions Reductions

CP: Carbon productivity

ECP: Embodied Carbon productivity

EER: Carbon emissions-employment Rate

EI：Energy Intensity

EU: European Union

GHG: Green House Gas

GW: Gigawatt[57]

ILO: International Labor Organization

IPCC: Intergovernmental Panel on Climate Change

KW: Kilowatt

kWh: kilowatt-hour

LCD: Low carbon development

LCE: Low Carbon Economy

LP：Labor Productivity

MW: Megawatt

NDRC: National Development and Reform Committee

NFPP: Natural Forest Protection Program

[57] 1 kW = 1000 watts. 1 MW = 1000 kW. 1 GW = 1 million kW.

NGO: Non-Governmental Organization

SFA: State Forestry Agency

Tce: ton of standard coal equivalent

UNEP: The United Nations Environment Program

UNFCCC: United Nations Framework Convention on Climate Change

WB: World Bank

# Annex 2: Data Mining and Resources

This study is rolled out along the following lines

- **Energy Intensity**: Namely the energy consumption of per unit of GDP. It is a measure of the energy efficiency of a nation's economy. The industry energy intensity refers to the amount of energy consumption of added value in a particular industry.
- **Carbon Economic Efficiency**: Namely carbon output or carbon productivity, it means carbon emission of per unit of GDP.
- **Carbon Cost Effectiveness:** It refers to the costs needed by per unit of carbon output. For example, the economic efficiency of thermal power is lower than that of wind power. But considering the cost of per unit, the economic efficiency of thermal power is considerably higher than that of wind power.
- **Carbon Employment Rate**: It refers to the corresponding labor input of per unit of carbon emissions, or the added number of employment corresponding to the added carbon dioxide emissions.

The formulae are as follows:

- **Labor productivity** (yuan/person) = GDP/employment = GDP/L
- **Energy Intensity** (tce/10,000yuan) = Amount of energy consumption/GDP = E/GDP
- **Sectoral Energy Intensity** (tce/10,000yuan) =Amount of energy consumption/sector added value= $E_i / GDP_i$
- **Carbon Productivity** (10,000yuan/tons of $CO_2$)=GDP/Total amount of $CO_2$ emission＝

  $$\sum_{1}^{i} GDP_i / \sum_{1}^{i}\sum_{1}^{j}(E_{ij} * e_j)$$

- **Sectoral Carbon Productivity** (10,000yuan/tons of $CO_2$) = sector added value/sector total emission of $CO_2$= $GDP_i / \sum_{1}^{j}(E_{ij} * e_j)$

- **Sector Carbon Employment Rate** (person/tons of $CO_2$)=sector total employment/industry emission volume of CO2 $= L_i / \sum_{1}^{j}(E_{ij} * e_j)$

Among these formulae, *GDP* means gross domestic production, $GDP_i$ means the added value of sector *i*. L means the number of employment, *E* stands for the amount of energy consumption. *i* here refers to the sector *i*, while *j* refers to the type of energy *j*. $E_{ij}$ refers to carbon emission factor of energy *j* in the sector *i*.

All the research data fall into the category of economic aggregate data, sectoral data, employment data, energy data, carbon emission data etc. The sources of the data are listed in the following table:

**Table 1-1：Data Collection and Resources**

| Type of data | Key indicators | Time series | Data resources |
|---|---|---|---|
| **Employment** | Sectoral employment numbers | 1978-2007 | CLSY； CPY； CPESY；CESY |
| | Labor productivity | 1978-2007 | CLSY； CPY； CPESY；CESY |
| **Energy** | The volume of total sectoral energy consumption | 1980-2007 | CENSY |
| | Sectoral end-use energy consumption in each type | 1990-2006 | CENSY |
| | Fossil fuels, $CO_2$ emission factor, etc | 1960-2005 | CDIAC/ORNL ； ERI |
| **Output** | GDP | 1978-2007 | CESY |
| | Added value of industry | 1970-2007 | CESY |
| | Fixed investment | 1980-2007 | CESY |
| **Sectoral data** | Forestry sector: forest area, investment for forest projects, forest coverage, carbon sink, etc. | | CFSY；SFA |
| | Power sector: installed capacity, etc | | SERC； SGCC； CHPG |
| **Comprehensive data** | Sectoral energy intensity | 1980-2007 | Calculated |
| | Sectoral CO2 emissions | 2005 | Calculated |

| Type of data | Key indicators | Time series | Data resources |
|---|---|---|---|
| | Carbon productivity | 1978-2007 | Calculated |
| | Sectoral carbon productivity | 2005 | Calculated |
| | Sectoral carbon-employment rate | 2005 | Calculated |

Note: CLSY: China Labour Statistical Yearbook

CPY: China Population Yearbook

CPESY: China Population & Employment Statistical Yearbook

CDIAC/ORNL: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory;

CENSY: China Energy Statistical Yearbook

CESY: China Economic Statistical Yearbook

CFSY；China Forestry Statistical Yearbook

SFA: State Forest Agency;

SGCC: State Grid Corporation of China；

CHPG: China Huaneng Power Group;

SERC: State Electricity Regulatory Committee

# Annex 3: Input-Output Analysis

## I. Methodology

### 1. Total Output Multiplier and Influence Coefficient

#### A. Direct input coefficients and cumulative input coefficients

Assume $X_j$ is the total output of sector j. Direct input coefficient of Sector j refers to the ratio of value of directly consumed goods or services in sector j during manufacturing and operation "$x_{ij}$" to the value of total output. i.e., direct input coefficient can be written as:

$$a_{ij}=x_{ij}/X_j$$

Direct input coefficient shows the value of goods or services in sector j which is the direct input during manufacturing and operation

Cumulative input coefficient is noted as $b_{ij}$, referring to the sum of value of goods and services in sector i directly consumed and indirectly consumed to produce one unit of product or services of j at end use. The equation of deriving matrix of cumulative input coefficients B from matrix of direct input coefficients A is as the following:

$$B=(I-A)^{-1}-I$$

#### B. Output Multiplier and Influence Coefficient

We define output multiplier as the sum of all induced outputs in different sectors of national economy when sector j produces one more unit of marginal product. Output multiplier can be written as:

$$M_j=1+b_{1j}+b_{2j}+b_{3j}+\ldots+b_{nj}$$

Output multiplier of a sector effectively shows its strength to promote national economy. The larger the value is, the more effectively it could promote economic development and the more jobs it could create.

Influence coefficient shows relative capacity of a sector to induce output. It has the same implication as output multiplier, indicating how the production of one more unit of marginal output in the sector could influence all other sectors of national economy. The equation of calculating influence coefficient $F_j$ can be expressed as follows:

$$F_j = \frac{\sum_{i=1}^{n} \overline{b_{ij}}}{\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \overline{b_{ij}}}$$

In this equation, $\sum_{i=1}^{n} \overline{b_{ij}}$ is the sum of value in column j of Leontief inverse matrix, and

$\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \overline{b_{ij}}$ is the average value of column sum in Leontief inverse matrix.

When $F_j > 1$, it indicates the influence of sector j production is larger than the average influence power in the economy, and vice versa. Apparently, the larger $F_j$ value a sector has, the more powerful it could promote the development of other sectors.

According to the 2005 National Input-Output Table of the State Statistic Bureau, we derived output multiplier and influence coefficient of 42 sectors, as shown in table 1.

**Table 1. Output Multiplier and Influence Coefficient of 42 Sectors**

| Sector | Output Multiplier | Influence Coefficient | Rank |
|---|---|---|---|
| Telecommunication Computer and other electronic equipment manufacturing | 4.1887 | 1.4383 | 1 |
| Meters, apparatus, and machinery for stationary | 3.7574 | 1.2902 | 2 |
| Transportation equipment manufacturing | 3.6929 | 1.2681 | 3 |
| Machinery and Equipment manufacturing | 3.6584 | 1.2562 | 4 |
| Metal Products | 3.5525 | 1.2199 | 5 |
| General and special Equipment manufacturing | 3.5136 | 1.2065 | 6 |
| Chemical Industry | 3.4765 | 1.1938 | 7 |
| rental and commercial services | 3.4477 | 1.1839 | 8 |
| Metal Smelting and pressing | 3.4214 | 1.1748 | 9 |
| Leather, Furs, Down and Related Products | 3.3909 | 1.1644 | 10 |
| Textile industry | 3.3823 | 1.1614 | 11 |
| Papermaking, Stationery, Educational Goods | 3.3129 | 1.1376 | 12 |
| Timber processing and Furniture Manufacturing | 3.3112 | 1.1370 | 13 |
| Construction | 3.2963 | 1.1319 | 14 |

| | | | |
|---|---|---|---|
| Sanitation and social welfare | 3.2469 | 1.1150 | 15 |
| Non-metal Mineral Products | 3.2429 | 1.1135 | 16 |
| Other Manufacturing | 3.2112 | 1.1027 | 17 |
| Scientific researches | 3.1411 | 1.0786 | 18 |
| Non-metal mineral processing | 3.1321 | 1.0755 | 19 |
| Production and supply of natural gas | 3.0536 | 1.0486 | 20 |
| Production and Supply of Electric Power, Steam and Hot Water | 3.0401 | 1.0439 | 21 |
| metal mineral processing | 3.0189 | 1.0366 | 22 |
| Polytechnical Services | 2.9831 | 1.0243 | 23 |
| Processing of Petroleum, Coking, Processing of Nuclear Fuel | 2.8843 | 0.9904 | 24 |
| Foodstuff and tobacco processing | 2.8104 | 0.9651 | 25 |
| Information Transmission, Computer Service and Software Enterprises | 2.7822 | 0.9554 | 26 |
| Coal Mining and Dressing | 2.7192 | 0.9337 | 27 |
| Water, Environmental and Public infrastructure | 2.7092 | 0.9303 | 28 |
| Water production and supply | 2.6811 | 0.9207 | 29 |
| Lodging and catering | 2.6780 | 0.9196 | 30 |
| Culture, fitness and entertainment industry | 2.6719 | 0.9175 | 31 |
| Transport, Storage and Communication | 2.6450 | 0.9083 | 32 |
| Postal & communication | 2.6404 | 0.9067 | 33 |
| Residential service and other services | 2.5979 | 0.8921 | 34 |
| Public Management and social organization | 2.3152 | 0.7950 | 35 |
| Education | 2.1497 | 0.7382 | 36 |
| Agriculture | 2.1134 | 0.7257 | 37 |
| Banking and Insurance | 2.0535 | 0.7051 | 38 |
| Oil & natural gas exploitation and development | 1.9436 | 0.6674 | 39 |
| Wholesale and Retail Sale Trade | 1.8853 | 0.6474 | 40 |
| Real Estate | 1.5588 | 0.5353 | 41 |
| Waste products or materials recycling | 1.0000 | 0.3434 | 42 |

Data source: calculated by author

## II. Direct, Indirect and Induced Marginal Employment

The assessment of employment effect of different sectors is based on effective analysis theory from the supply chain perspective. The Induced effect of a sector refers to the effect on upstream and downstream industries when the end demands of such sector change. The affected upstream and downstream industries will further affect their upstream and downstream industries, hence affecting the whole economy. However, such effect will diminish with economic expansion until to zero. To evaluate such output expansion's overall effect on employment, the definitions of different kinds of employment needs elaboration. **Direct employment** of a sector is defined as jobs created in such sector to expand manufacturing when output increases; **indirect employment** is defined as jobs incurred by the production of inputs to the specific sector in its production process; **induced employment** refers to the sum of all other jobs created during the production expansion.

### III. Labor Coefficient and Employment Influence Coefficient

**Labor coefficient** in sector I is defined as:

$$L_i = {M_i}/{X_i}$$

$M_i$ refers to the total number of employers in sector *i*; $X_i$ refers to the total output of sector *i*. Labor coefficient is an indicator of how output changes affect employment in a specific sector. However, output changes in a sector also induce employment changes in related sector. Direct input coefficient shows how one additional unit of marginal product in one sector affects first expansion in other sectors. Multiplying increased output in one sector with the labor coefficient of such sector, we could get indirect marginal employment induced. As a result, we can define **indirect employment coefficient** $I_i$ as:

$$I_i = L_1 a_{1i} + L_2 a_{2i} + \ldots + L_n a_{ni}$$

As we defined **induced employment** coefficient $K_i$ as the sum of employment incurred after the first round of production expansion, we get the equation for calculating $K_i$:

$$K_i = L_1 b_{1i} + L_2 b_{2i} + \ldots L_j b_{ji} + \ldots + L_n b_{ni} - I_i$$

Table 2 shows the labor coefficient and marginal employment effect calculated based on data from Input-output Table of 2005 and from "China Labor Statistical Yearbook 2006"[58].

[58] Only data on urban employment is available from China Labor Statistical Yearbook, as a result, this paper only examine urban employment.

**Table 2. Labor Coefficient and Marginal Employment Effect**

| Sector | Labor Coefficient | Indirect Marginal Employment Coefficient | Induced Marginal Employment Coefficient | Rank |
|---|---|---|---|---|
| Education | 0.1624 | 0.0081 | 0.0121 | 1 |
| Water, environmental and public infrastructure management | 0.0944 | 0.0126 | 0.0180 | 2 |
| Public Management and social organization | 0.0968 | 0.0107 | 0.0132 | 3 |
| Postal & communication | 0.0849 | 0.0113 | 0.0171 | 4 |
| Sanitation and social welfare | 0.0539 | 0.0111 | 0.0236 | 5 |
| Scientific researches | 0.0492 | 0.0122 | 0.0220 | 6 |
| Water production and supply | 0.0530 | 0.0102 | 0.0191 | 7 |
| Coal Mining and Dressing | 0.0476 | 0.0105 | 0.0185 | 8 |
| Culture, fitness and entertainment industry | 0.0448 | 0.0113 | 0.0170 | 9 |
| Polytechnical Services | 0.0351 | 0.0148 | 0.0206 | 10 |
| Production and supply of natural gas | 0.0234 | 0.0202 | 0.0219 | 11 |
| Leather, Furs, Down and Related Products | 0.0217 | 0.0138 | 0.0257 | 12 |
| Construction | 0.0232 | 0.0105 | 0.0237 | 13 |
| Rental and commercial services | 0.0212 | 0.0111 | 0.0248 | 14 |
| Textile | 0.0177 | 0.0125 | 0.0247 | 15 |
| Banking and Insurance | 0.0350 | 0.0091 | 0.0105 | 16 |
| Meters, apparatus, and machinery for stationary | 0.0156 | 0.0100 | 0.0282 | 17 |
| Transportation equipment manufacturing | 0.0138 | 0.0111 | 0.0281 | 18 |
| Production and Supply of Electric Power, Steam and Hot Water | 0.0114 | 0.0174 | 0.0217 | 19 |
| Telecommunication Computer and other electronic equipment manufacturing | 0.0084 | 0.0095 | 0.0323 | 20 |
| General and special Equipment manufacturing | 0.0142 | 0.0101 | 0.0259 | 21 |

| | | | | |
|---|---|---|---|---|
| non-metal mineral processing | 0.0135 | 0.0119 | 0.0242 | 22 |
| Other Manufacturing | 0.0159 | 0.0110 | 0.0225 | 23 |
| Transport, Storage and Communication | 0.0228 | 0.0094 | 0.0170 | 24 |
| Papermaking, Stationery, Educational Goods | 0.0130 | 0.0111 | 0.0238 | 25 |
| Chemical industries | 0.0109 | 0.0107 | 0.0263 | 26 |
| Electronics, Machinery and Equipment manufacturing | 0.0101 | 0.0098 | 0.0274 | 27 |
| metal Mineral Products | 0.0149 | 0.0101 | 0.0221 | 28 |
| Non-metal Mineral Products | 0.0117 | 0.0109 | 0.0226 | 29 |
| Metal Products | 0.0090 | 0.0092 | 0.0265 | 30 |
| Timber processing and Furniture Manufacturing | 0.0104 | 0.0107 | 0.0235 | 31 |
| Metal Smelting and pressing | 0.0085 | 0.0100 | 0.0251 | 32 |
| Wholesale and Retail Sale Trade | 0.0281 | 0.0055 | 0.0090 | 33 |
| lodging and catering | 0.0162 | 0.0093 | 0.0159 | 34 |
| Information Transmission, Computer Service and Software Enterprises | 0.0131 | 0.0078 | 0.0183 | 35 |
| Foodstuff and tobacco processing | 0.0103 | 0.0097 | 0.0163 | 36 |
| Processing of Petroleum, Coking, Processing of Nuclear Fuel | 0.0044 | 0.0135 | 0.0174 | 37 |
| Residential service and other services | 0.0082 | 0.0095 | 0.0166 | 38 |
| oil & natural gas exploitation and development | 0.0153 | 0.0051 | 0.0102 | 39 |
| Agriculture | 0.0113 | 0.0059 | 0.0106 | 40 |
| Real estate | 0.0143 | 0.0046 | 0.0057 | 41 |

Data source: calculated by author

The Coefficient in the table shows the number of jobs created with increased output of RBM10,000 yuan in the sector. Take “Residential services and other services” as an example, the labor coefficient, indirect marginal employment coefficient and direct marginal employment coefficient respectively shows for each additional output of RBM10,000 yuan in the sector, 0.0082 job is created directly in the sector; in production process, 0.0095 job is incurred by the direct supply of input necessary; besides, 0.0166 job is created in the whole production expansion process; thus, 0.0342 job is created in total for all sectors in the supply chain.