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Study on Low Carbon Development and Green Employment in China

Institute for Urban and Environmental Studies (IUE)
Chinese Academy of Social Sciences (CASS)

Green Jobs in China

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The research team bears sole responsible for the reliability of the data, literature sources and research findings.

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Executive Summary

I. Background

Adaptation and mitigation are the two major responses to tackle the effects of climate change. Designing mitigation policies and introducing low carbon technology are important ways to promote low carbon development. Low carbon development refers to the process of achieving a low carbon economy by way of developing sustainably and addressing climate change. Low carbon development and technological advancement can be achieved by implementing policies such as eliminating outdated production facilities and developing new technology and new energy. The implementation of such policies will bring about changes to the industrial structure and energy mix, thus impacting different sectors and the employment structures within them.

From 2008, against the backdrop of climate change and the global financial crisis, China has been working towards low carbon development by designing and implementing policies that promote energy efficiency and emission reductions. At the United Nations summit on climate change in September 2009, President Hu Jintao indicated China's intention to move towards an environmentally friendly and low carbon economy in his speech entitled "Joining Hands to Address the Climate Challenge". Hu stated that in working toward the emissions reduction target set out in the Eleventh Five-Year Plan, China will make further efforts to: firstly, promote energy efficiency and sharply reduce carbon emissions by 2020; secondly, develop renewable energy, nuclear energy and increase the share of clean energy generation to 15%; thirdly, increase the carbon sequestration capacity of the forestry sector; and fourthly, develop and introduce climate-friendly technologies. On 26 November 2009, ahead of the UNFCCC's COP15 talks, the Chinese government announced a voluntary target to reduce by 2020 carbon emissions per unit of GDP by 40 to 45% of 2005 levels. Such quantitative targets demonstrate China's commitment to firmly engage in low carbon development, and have profound and far reaching impacts on promoting green employment and low carbon employment in China.

The ILO defines "green jobs" as those that reduce the environmental impact of enterprise and economic sectors, to levels that are sustainable. Similarly, "low carbon employment" can be defined as employment created in economic sectors and activities which are able to promote enterprise and industry to reduce fossil fuel consumption and carbon dioxide emissions and mitigate global greenhouse gas emissions. For example, low carbon employment includes employment in industries such as afforestation and reforestation, the production and supply of clean energy, resource recycling and reuse, eco-agriculture, energy-saving buildings, and public transport etc. In essence, any jobs created in sectors and enterprises that can promote low carbon development are green. [1]

II. Addressing Major Sectors

By influencing investment flows, low carbon development will have different impacts on output and employment in different industries. This study selected the areas most significantly affected by low carbon development policies, and focused on three major sectors in which to analyze the employment effects. In addition, in consideration of China's four trillion stimulus response to the global financial crisis, the research team estimated the employment effect of the green investment component of the stimulus package, the spending of which is most closely related to climate change. The composition of the relevant sectors and data sources are shown below:

1 As a low carbon economy can be regarded as a new way to achieve a green economy, the concept of green employment mentioned in this report includes the concept of low carbon employment. Low carbon employment is employment in all related environment-friendly industries which is able to promote low carbon development. The employment effect of desulfurization in the thermal power sector is one example. The industry promotes reducing sulfur dioxide emissions, but it can not reduce carbon dioxide emissions. Given that desulfurization in the thermal power sector is an important part of environmental policy in China, namely the Energy-saving and Emissions Reduction Policy, and carries significant social and environmental benefits, the research team has estimated the effects of green employment in the thermal power sector.

Sectors	Sub-sectors	Period	Data Sources[2]
Forestry	Afforestation & Reforestation	2005-2020	Forestry industry yearbooks; literature reviews; expert consultation.
	Sustainable Development Forestation	2005-2020	Literature reviews; specific research reports and official documents; expert consultation.
	Forest Tourism	2005-2020	Tourism industry yearbooks; literature reviews; expert consultation.
Power Generation	Thermal Power	2005-2020	Field investigations and telephone interviews in selected enterprises; literature reviews; specific research reports and official documents; expert consultation.
	Wind Power	2005-2020	Field investigations and telephone interviews at selected enterprises; literature reviews; specific research reports and official documents; expert consultation.
	Solar Power	2005-2020	Literature reviews; specific research reports in the sector; expert consultation.
Core industry	Iron and Steel	2007-2011	The Iron and Steel Industry Yearbook; telephone interviews in firms; expert consultation.
The four trillion National Stimulus Package	Green Investment	2008-2011	Literature reviews; official documents.

To calculate the employment effects of low carbon development policies on the above industry sectors, this study uses broader definitions for the sectors than those used in previous research, defining a sector with its entire industrial chain included i.e. from raw material production and equipment manufacturing to product supply and marketing etc. For example, in the power generation sector, the industry chain mainly consists of: power generation and supply (including management and maintenance); manufacturing of electrical equipment and related facilities; electric power technology research and development; and technical consultation and after-sales services.

Increasing energy-efficiency, reducing emissions and ecosystem conservation are all important policy measures for promoting low carbon development in China. The former two measures will adversely affect employment in the fossil fuels-related sectors, however, technological advances and reduced operating costs will benefit the long-term development of the entire economy. Meanwhile, the conservation positively impact employment in the forestry sector, including afforestation and reforestation activities, forest ecosystem management and forest tourism etc.

III. Defining the Employment Effects

The employment effects of low carbon development fall into three categories:

- **Direct employment** – employment related to the increase in the output of goods for a specific sector.
- **Indirect employment** – employment related to an increase in the input of goods from the suppliers of that sector, with a rippling effect through the supply chain.
- **Induced employment** – as a result of the effect on the supply chain and an increase in income in the economy, employment related to the spending of that increased income.

Therefore, the total effect of low carbon development on employment is the sum of direct, indirect and induced employment.[3]

[2] Other references and sources include: Industrial Economy Statistics, Yearbook, China Statistics Yearbook, Labour and Employment Statistics Yearbook, China Population and Employment Yearbook, and World Development Bank Indicators etc.

[3] This study draws on the concepts of direct, indirect and induced employment as defined by the ILO. Due to limitations associated with methodology and data, this report focused on the effects of direct and indirect employment in major sectors only. If the effect of induced employment is taken into account, the long-term impact on employment of China's low carbon development policies would certainly be more salient.

Based on reviews of domestic and international literature, enterprise-level field investigations and input-output analysis etc, this study focused on the effects of the Energy-saving & Emission Reduction Policy on employment in major industry sectors such as forestry, electric power, iron and steel. In addition, the study also explored the potential employment effects of the green investment component of China's four trillion economic stimulus package.

IV. The Employment Effects of Low Carbon Development in Major Sectors

Forestry Sector

The development of the forestry sector and environmental conservation are important in effectively managing climate change and achieving low carbon development.

The positive impacts of climate change on the forestry industry include: increases in government investment and the launching of forestry eco-projects that stimulate increased employment; and the emergence of new low carbon industries such as carbon sequestration, biomass, forestry products, eco-tourism and forest sustainable management etc. These sectors extend the forestry industrial chain and create new employment opportunities.

The negative impacts on the forestry industry include: restrictions to the wood logging and processing industries resulting in the lay-off of workers; and changes to the distribution of forests affecting forest management enterprises by increasing the prevalence of droughts, fires and forestry pests and diseases. Extreme weather conditions also impact the forestry sector and related industries such as forestry infrastructure, tourism and transport which are particularly susceptible to sleet, snow, floods and landslides etc.

In global terms, the forestry industry can make a positive contribution to climate change mitigation by increasing carbon sinks, carbon storage and carbon substitution. Research results show that many kinds of forestry initiatives address climate change, such as afforestation, forest management and forest tourism. Initiatives in these sectors can create large numbers of green jobs, strategic to tackling climate change and easing the unemployment pressures brought about by the global financial crisis. They will also promote industry restructuring in China.

Studies show that between 2005 and 2020, the forestry industry has the potential to create more than 25 million jobs. Of these jobs:

- 7.8 million direct and nearly 19 million indirect green jobs will be generated in the **afforestation, reforestation and forest management** sectors;
- 6.8 million direct and indirect green jobs will be created in the **forest tourism** sector, driven by the development of tourism-related services such as catering and transport etc.[4]

From these results it is evident that the forestry industry will play a very significant role in promoting low carbon development and green employment.

Sectors		**Direct employment**	**Indirect employment**	**Total**
Forestry	Afforestation and Reforestation	7.6 million	11.09 million	18.69 million
	Sustainable Forest Management	166,900 – 208,600	54,000 – 67,500	220,900 – 276,100
	Forest Tourism	3.15 million	3.62 million	6.77 million
Total		**25.68 - 25.73 million**		

Employment effects of low carbon development in the forestry industry from 2005 to 2020 (Number of jobs)[5]

This study makes the following policy recommendations for the development of the forestry industry and green jobs creation:

[4] The data used here refers to jobs created in forest parks only and does not take into account other formal and informal jobs in tourism related to forest parks. Therefore the numbers will be underestimated.

[5] Due to inconsistencies in the research methodologies used, only the indirect employment effects of forest tourism have been calculated. This is because employment created by forestation is based on data converted from labour inputs, which although is mostly made up of informal employment, it is not comparable with the official labour and employment statistics. Therefore the indirect employment induced by afforestation and management with input-output analysis has not been calculated.

(1) The forestry sector and sustainable afforestation projects should be supported and developed to create more jobs and alleviate China's current employment pressures.

(2) The forestry management system should be reformed. For example, establishing carbon sink forestry will require more government investment in afforestation projects; a market for carbon sinks utilizing a carbon emission trading system should be established; and awareness raising activities undertaken to promote employment opportunities in carbon sinks.

(3) The forest tourism sector should be developed to generate green and low carbon jobs. Forest tourism is strongly correlated with many service industries, and has much potential for creating direct and indirect jobs. It is recommended that forest tourism is planned as an entire sector – an increase in investment and in construction projects will create flow-on effects in related service industries and create green jobs.

(4) Measures to minimize the negative employment effects forecast to hit forestry-related sectors should be adopted. For example, afforestation projects will by nature reduce employment in agriculture, while projects that focus on forestry protection will negatively impact employment in enterprises that use forestry products. Therefore, the government, private sector and relevant forestry departments need to work together to mitigate these negative impacts by strengthening training and transferring displaced workers to new jobs. Re-employment programs for laid-off workers and the development of alternative sectors which can bring new employment opportunities must also be advocated.

(5) Forestry workers should be given assistance to upgrade their skills, coupled with programs that increase workers' awareness of the concept of decent jobs. Studies show that China's forestry sector has enormous potential for low carbon development and green employment. Many new sub-sectors are yet to emerge in areas such as carbon sequestration; forest management; forest health products, including those that re-use and replace natural products, and forest recreation etc. Strengthen social security, skills training and employment services in the forestry sector to enhance the awareness and capacity of forestry workers towards decent jobs. This can be achieved through promoting awareness of the concept decent jobs, public campaigns and training and education

Power Generation Sector

The implementation of a low carbon development strategy in the power industry will impact on green jobs in two contrasting ways. Firstly, policy measures geared towards energy-efficiency and emission reductions will force the closure of inefficient small-scale thermal power units, resulting in job losses. Secondly, low carbon energy generation and the introduction of desulphurization projects in the thermal power sector will jobs to increase.

During 2005 to 2020, the implementation of low carbon development policies in the power generation sector is forecast to create 4.4 to 5.05 million new green jobs, with indirect jobs expected to be the most prominent. Indirect positions will be the result of both increased investment within the power generation sector and changes to the structure of employment.

Power Sector	Sub-sectors/ Activities	Direct Employment	Indirect Employment	Subtotal	Total
Thermal Power	Closing small & inefficient units	- 47,500	-753,860	-801,360	279,160
	Desulfurization	298,020	782,500	1.081 million	
Wind Power	Wind power generation	156,000-208,000	533,000- 711,000	689-919	2.83-3.484 million
	Wind power equipment manufacturing	606,000- 726,000	1.535-1.839 million	2.141-2.565 million	
Solar Power	Solar PV generation	50,300	1.2371 million	1.2371 million	1.2874 million
Total	**4.397-5.051 million**				

Green jobs in the power generation sectors in China in 2005-2020 (Number of jobs)[6]

[6] Analysis of the employment effects on the power generation sector should be based on large scale research at the enterprise level. Due to time and human resource limitations, this study did not address the employment effects relating to research and development and other services within the sector and only calculated the direct and indirect employment effects in major sub-sectors like power generation and power generation equipment manufacturing. Therefore, the true employment effects are expected to be higher than those shown in the results table.

There will be a variety of impacts on employment in the power generation sectors during 2005 to 2020, due to the differing impacts of the low carbon development, energy-efficiency and emissions reduction policies within each sector.

- **Thermal Power Sector:** The energy efficiency and emissions reductions policy measures will impact employment in the thermal power sector in two ways. Firstly, the replacement of high-coal consumption and low efficiency small thermal power units with high energy efficiency ones will result in a net decrease in employment. From 2005 to 2020, this policy is expected to directly and indirectly cause 800,000 jobs losses. Secondly, from 2005 to 2020, thermal power desulphurization projects will lead to the creation of 1.08 million direct and indirect green jobs including sub-sectors relating to the design, manufacture, installation and maintenance of desulphurization equipment. There will therefore be an overall positive impact on employment in the thermal power industry with a net increase of around 280,000 jobs.

- **The Wind Power Sector:** In 2005-2020, a total of 2.83 to 3.48 million new green jobs will be created in wind power generation. Of these new jobs, 690,000 to 920,000 will be created in wind power enterprises and 2.14 to 2.57 million in manufacturing wind power equipment, an average of 180,000 to 220,000 new jobs each year. If a rational development plan for the wind power sector can be designed, and enterprises in wind power equipment manufacturing are encouraged to increase research and development investment and improve productivity and technical performance, positions in traditional manufacturing will be transferred to green jobs.

- **The Solar Power Sector:** The results of the study show that between 2005 and 2020, there will be 440,000 to 650,000 direct and 430,000 to 620,000 indirect jobs created in the solar PV sector. Investment in solar power generation over the same period will generate direct jobs of up to 50,300 and indirect jobs of around 367,700.

As low carbon development policies have different employment effects on enterprises within the power generation sector, policies to create green employment must focus on the following areas:

(1) **Promoting renewable energy and increasing the number of green jobs in the power sector.** In recent years, the rapid development of China's power industry has meant that the proportion of jobs within the coal-fired power sector have increased, making it increasingly difficult to improve energy-efficiency and reduce emissions. Therefore, low carbon energy generation should be promoted to speed up the replacement of inefficient thermal power units and bring about more green jobs.

(2) **Establish a training system to up-skill workers as the employment structure within the power generation industry changes.** The ability of the sector to adapt to new technology and cope with a shortage in human resources capable of managing low carbon energy will determine whether energy-efficiency and emission reductions targets are met. The power generation industry must also manage the relocation of laid-off workers, particularly those in the thermal energy sector, displaced by the closure of small thermal power units. On one hand, shutting down small inefficient thermal power units is necessary to create momentum for technical training that will improve the energy efficiency and operating standards of medium and large units. On the other hand, equal focus must be given to training that encourages collaboration between enterprise and vocational colleges. Specialized training will enable the sector to meet the future industry needs brought about by the generation of low carbon energy.

(3) **Develop international and domestic markets for power technology and expand the channels for green employment.** To narrow the technology gap between China and developed countries, more human resource and capital investment are required in low carbon technology marketing and research and development. Technology should be developed using policies that encourage cooperation between enterprise and research institutions so to continuously promote employment in the low carbon energy generation industry. The establishment of Chinese low carbon enterprises overseas will help to expand the sector within domestic and international markets, and increase domestic employment.

(4) **Provide policy support to the low carbon energy power generation sector, to facilitate industry growth and create green jobs.** In China, the low carbon energy power generation sector has faced considerable setbacks due to the global financial crisis. Industry competition is increasingly fierce and some enterprises are not transitioning well and are in danger of being shut down. Preferential fiscal and taxation policies will encourage enterprise to invest in low carbon, energy efficient and environmentally responsible power generation equipment, such as wind turbines, solar power and biomass equipment etc.. This will in turn, promote the development of upstream and downstream industries and green employment.

Basic Industry

Based on analysis of the output, employment and energy consumption in China's major sectors, the energy intensity of basic industry fell by an average of 1.91% between 1985 and 2002. The Eleventh Five-Year Plan target to reduce energy consumption and reduce emissions by 20% means that the energy intensity of core industry needs to fall by 4.4% each year. Due to the elasticity of the basic industry sector in terms of the effects of energy on employment, total job losses to the sector between 2005 and 2010 are estimated to be 15.34 million, with an average annual loss of 3.068 million. As a key sector of basic industry, the employment effects of low carbon development in the iron and steel industry should be analyzed in detail.

Urbanization has driven ten years of rapid growth for the iron and steel industry in China. However, the sector now faces problems such as excess capacity, wide differences in workers' technical skill levels and a low industrial concentration rate[7] etc. As the iron and steel industry is a big contributor to energy consumption and pollutant and greenhouse gas emissions, it is one of the key sectors targeted by the government's energy efficiency and emissions reduction policies.

The iron and steel industry can address meeting policy targets in three ways: through replacing excess capacity, adopting technology that will create energy efficiencies and reduce emissions and through production process improvements.

In terms of excess capacity, China is working towards shutting down outdated production facilities. During 2007 to 2011, it is estimated that job losses in the iron and steel industry will be around 390,000 to 400,000. However, 200,000 direct jobs are expected to be created purely due to the sector's size and from the adoption of advanced technology. This will reduce the net effect of job losses by 190,000 to 200,000.

Policy recommendations for the promotion of low carbon development and green jobs in the iron and steel industry are as follows:

(1) **Improve policies related to the transfer and re-employment of workers laid off from the closure of thermal power units.** For example, the costs to enterprises can be reduced by providing incentives and subsidies to workers and allocating a proportion of new positions to laid-off workers.

(2) **Introduce government subsidies to relieve the operating costs of small and medium-sized enterprises.** As investment in emissions reduction technologies will increase enterprises' operating costs, subsidies will help to both encourage the adoption of energy-saving and emission reduction technologies and enhance the green employment potential of the industry and foster its long-term healthy development.

(3) **As steel production increases, encourage the recycling of scrap metal and other raw materials to promote the recycling sector and increase green employment.** For example, developing the EAF Steelmaking Process will reduce energy consumption and greenhouse gas emissions and boost employment.

(4) **Manage the impact on employment of low carbon development.** Employment opportunities can be increased through the promotion of energy efficiency and emissions reduction technologies and recycling. Employment-generating initiatives such as transferring workers to alternative positions, creating jobs in philanthropic projects, and prioritizing skills training for displaced workers are ways to mitigate the negative impacts of low carbon development.

Green Investment in China's Economic Stimulus Package

The 2008 the global financial crisis significantly impacted the Chinese economy by creating an increased dependence on exports. A decline in both imports and exports brought about by the crisis caused an unemployment wave through China's export-oriented coastal regions, also impacting other domestic upstream and downstream sectors. As a result, in November 2008, the Chinese government introduced an economic stimulus package of four trillion Yuan. This package included a two-year plan to expand government investment and achieve sustainable growth, adjust the structure of the economy to increase domestic demand and promote employment policy objectives.

Changes to the economic structure will bring about different effects on employment. This study defines the stimulus package investment most closely related to low carbon development as "green investment", and measures this investment based on its potential impact on employment. The green investment component can be further separated into three parts most closely related to climate change and include projects in: energy efficiency, emission reductions and

[7] Industrial concentration rate or market concentration rate refers to the competitiveness of key enterprises within a specific sector e.g, the rate of production, sales, and capital assets of several big enterprises. The indicator can reflect the extent that the sector or country can achieve economies of scale and market competitiveness.

eco-engineering; industry restructuring and technical transformation; and rural biogas. Total planned green investment is RMB 598.5 billion or 15.0% of the total stimulus package.

The table below measures the effect of green investment by looking at the industrial expansion across the economy as a whole. The results take into account the relationship between green investment and the input-output table for the output multiplier, the labour coefficient and the coefficient for the indirect employment effects:

- **Investment for energy-efficiency, emissions reductions and eco-building:** Investment in this area will increase the economy's total output by about 698.15 billion Yuan, creating over 200,000 green jobs;
- **Investment in structural adjustment and technical transformation:** Using two different scenarios, output-pull and employment- pull, investment in this area will create 230,000 to 240,000 green jobs respectively; and
- **Investment in rural projects:** Biogas projects will contribute about 59 billion Yuan to the economy, creating a corresponding 90,000 green jobs.

Green Investment		Direct	Indirect	Total
Energy-saving, Emission Reduction and Eco-building		56,700	151,700	208,400
Structural Adjustment & Technical Transformation[8]	Output-priority	71,600	151,200	222,800
	Employment-priority	92,000	141,900	233,900
Rural Livelihood Projects (bio-gas projects)		26,300	63,600	89,900
Total[9]		**175**	**357.2**	**532.2**

Employment effects of green investment in China's economic stimulus package (Number of jobs)

Overall, the green investment component of the economic stimulus package will contribute about 5.3 million green jobs to the Chinese economy.

Based on the above analysis, two policy recommendations are proposed. Firstly, when programs for economic structural adjustment are designed, emphasis should be given to employment and economic growth. In terms of investment, priority should be given to policies that are angled towards employment as increased employment will drive up incomes and consumption. Secondly, as is often observed overseas, green investment should focus on market development and increasing enterprises' capacity to innovate. This is an important foundation for ensuring long-term sustainable development. It is also recommended that the proportion of investment allocated to small and medium-sized enterprises for industry restructuring is increased to encourage enterprise to move into the tertiary sector and develop new technologies and technical services. Financial and tax incentives will encourage enterprise to innovate and invest in research and development of low carbon technology. This will set a solid foundation for scientific research and technical support of low carbon development.

The Total Employment Effects of Low Carbon Development in China

Low carbon development will generally have a positive impact on employment in China. As demonstrated in the table below, from 2005 to 2020, new green investment in sectors such as forestry, power generation and iron and steel will create more than 30 million green jobs.

Sectors	Sub-sectors	Direct Employment	Indirect Employment	Total
Forestry (2005~2020)	Afforestation & Reforestation	7.6 million	11.085 million	18.685 million
	Sustainable Forest Management	188,000	61,000	249,000
	Forest Tourism	3.154 million	3.616 million	6.77 million
Power Industry (2005~2020)	Thermal Power	251,000	29,000	279,000
	Wind Power	848,000	2.309 million	3.157 million
	Solar Power	50,000	1.237 million	1.287 million

8 It is assumed that there are two scenarios for investment in structural adjustment and technical transformation: 1) The Output-pull scenario where about 80% of the investment is in secondary industry and the remaining 20% is in tertiary industry; and 2) The Employment-pull scenario where about 60% of investment is in secondary industry, while 40% is in tertiary industry. These two scenarios have policy implications because as they are based on different policy objectives - the same proportion of investment will bring about different effects on policy.

9 The total uses data from the employment-pull scenario for industrial restructuring and technical transformation.

Basic Industry	Iron and Steel (2007~2011)	-200,000	--	-200,000
Green Investment (2008~2011)		175,000	357,000	532,000
Total[10]		30.759 million		

Total employment effects of low carbon development in major sectors in China(Number of jobs)

Policies which encourage energy-efficiency, emissions reductions and the closure of outdated production facilities will bring about a large number of jobs in traditional sectors such as thermal power and iron and steel. However, green sectors like forestry and clean energy hold great potential for creating low carbon jobs. In addition to the direct employment effects caused by these sectors, forest tourism, wind power and solar power will also play a role in driving output expansion and employment in upstream and downstream industry chains.

Green investment accounts for 15% of the Chinese government's four trillion economic stimulus package and has the potential to create over 5.3 million jobs. Slow domestic demand in China along with the needs to adjust the structure of industry and transform the patterns of economic growth are further reasons why the proportion of green investment within the economic stimulus plan should be increased. This will help to promote low carbon development and achieve the dual targets of economic development and employment.

V. Policy Recommendations

Low carbon development calls for economic development with low energy consumption, pollutants and emissions. This research analyses the impacts of low carbon development on employment in order to highlight the need for policies that take employment into account across all industries. To this end, the following policy recommendations are proposed:

- **Promoting low carbon employment through low carbon development**: In general, low carbon development promotes employment in various industries. Low carbon development carries great development opportunities in newly emerging industries such as forestry, wind power and solar power, thus creating low carbon employment.
- **Developing low carbon service industries and optimizing China's industrial structure**: Industrial and employment policies should support the development of tertiary industry, in particular consumer services which drive domestic demand. Sectors such as manufacturing should be provided with services that support technology and research; and high value-add primary industries such as eco-agriculture, forestry and specialized agricultural should be supported .
- **Encouraging employment-oriented green investment**: The four trillion Yuan economic stimulus package is mostly in favor of infrastructure projects such as those in transportation, construction and urban and rural reconstruction. Low carbon development should be fully embodied in the design of infrastructure projects to avoid a "carbon lock-in" effect; and the proportion of green investment should be increased to increase employment and achieve structural optimization.
- **Focusing on decent jobs as essential to green employment**: Green employment does not necessarily mean green jobs which are decent. Therefore, green employment must bring job security, welfare and guide the labour force transition towards decent work.
- **Step by step promotion of low carbon employment pilots**: Pilot programs should be launched in selected regions and in representative industries (or enterprises) with adequate communication of pilot activities to share experiences and lessons learned. The pilots will be form the backbone for policies which promote low carbon employment. The associated policy support in areas such as in finance, tax, training and social security will also need to be coordinated.

[10] Due to different methodologies and data sources, the total is used as a reference only as it includes incomparable data between sectors such as forestry and iron and steel. Some of the employment data in the table also uses values which are averages.

PART I. Policy and Research Context

1. Research Background

Climate change has become a global challenge and is a main focus of the international community in achieving sustainable development. The Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC) brought more scientific and technical information and evidence of climate change and pointed out that there are important benefits in taking earlier than later action to reduce greenhouse gas emissions and reduce the risks of global warming. The Stern Review[11] on the Economics of Climate Change, issued by the UK Government in October 2006, warned that the cost of climate change inaction would be between 5% and 20% of GDP each year. The Stern Review also highlighted the need for a major increase in the scale of international financial flows to sustain the emergence of a global low carbon economy.

To tackle climate change and its impacts for sustainable development, the United Nations Framework Convention on Climate Change *(UNFCCC)* and the *Kyoto Protocol* were adopted in 1992 and 1997 respectively, on the basis of a set of principles, including the important notion of common but differentiated responsibility. At a national level, a number of countries have realized the necessity to reduce their dependence on fossil fuels and have initiated a switch to low carbon development. In February 2003, the British government first put forward the notion of a low carbon economy in the *Energy White Paper: Our Energy Future—Creating a Low Carbon Economy*. In particular, the paper highlighted that the development of a low carbon economy was both technically and economically feasible. Later in 2007, the UNFCCC highlighted the long term necessity of a global low carbon economy, considered to be as essential to human development as the first industrial revolution. The concept of a low carbon economy has roused the interest of many countries engaged in the global fight against climate change. For instance, Japan is committed to building a low carbon society and Chinese cities such as Shanghai, Baoding, and Jilin have taken initiatives to promote a low carbon development.

Low carbon development will have a prominent impact on global employment. Adaptation and mitigation are the two main measures for addressing climate change. Mitigation measures include economic restructuring, the development and deployment of low carbon technologies and improving resource and energy efficiency. Low carbon development is a mode of development necessary to bring about a low carbon economy and tackle climate change. The process of de-carbonization will impact employment from both an industrial and regional perspective.

There is a growing concern in China towards low carbon development. The government's *Energy Saving and Emissions Reduction Strategy* is a key policy instrument which facilitates engagement in low carbon development. The policy, developed as part of the Eleventh Five-Year Plan, puts forward a target of a 20% reduction in energy intensity per unit of GDP (energy consumption per unit of GDP) in 2010 compared to 2005 levels. On 28 November 2009, China imposed a voluntary target to reduce by 2020 energy intensity per unit of GDP by 40 to 45% of 2005 levels. This target brings China closer to the low carbon development target called upon by the international community and will guide policy in achieving emissions reductions.

In anticipation of the potential impacts of low carbon development on different economic sectors, the research focused on the relationship between low carbon development and employment in China. The research also aims to support China's dual policy objectives of realizing low carbon development and employment promotion.

The main objectives of the research project are to:

1. Study the current status and future trends of low carbon development and green employment;
2. Estimate the number of jobs created and lost in newly emerging industries and traditional sectors;
3. Make recommendations for the promotion of low carbon policies and green employment that support the overall objective of sustainable development.

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

2. Policy and Key Concepts

2.1 Low carbon development

The term “low carbon economy” emerged in the late 1990s as attention towards climate change grew. In China, a commonly accepted definition of a low carbon economy is “a form of economy with low energy consumption and low pollutants and emissions”[12]. It has been held that “a low carbon economy or an economy low in greenhouse gas emissions or fossil fuels”, is ”the only way towards achieving sustainable development that meets the challenges of energy resources, environment and climate change”[13].

Low carbon development is a mode of development which aims to achieve a low carbon economy through a process of de-carbonization, while contributing to sustainable development and tackling climate change. As the greatest share of emissions of green- house gases comes from the use of fossil fuels, there are two ways to limit fossil fuel emissions:

- Reduce the share of fossil fuel based sources of energy and enhance the supply of clean energy;
- Reduce the demand for fossil fuel based sources of energy, in particular through measures and policies for energy efficiency;

In the short term, China can reduce carbon emission by promoting energy efficiency and carbon productivity measures without much change to energy and industrial infrastructures. In the long term, however, technological development can play a significant role in reducing emissions by way of adequate policies and measures e.g. by developing the supply of clean energy and increasing jobs relating to low carbon technology. Therefore, low carbon development is a way to reduce the share of natural resources and energy consumption per unit of output, while there is a constant increase of output in the economy.

In the context of the 2008 global financial crisis, major economies such as the USA, China and Britain have put measures in place to encourage green investment that fosters low carbon development and the green employment creation.

2.2 The low carbon economy (LCE) and employment: An overview

The development of the LCE will inevitably promote job creation and influence the labour market through optimizing or upgrading the industrial structure. In the long term, the driving factor of developing LCE is to promote technological advancement, including improving energy efficiency and developing renewable energies. As a rule, the development of the LCE will have a direct (either negative or positive) impact on the labour market in the energy sector and in energy intensive industries, and will have an indirect impact on the job market in other and particularly in emerging sectors linked to the ‘green economy’.

The policies and measures relating to climate change mitigation can have both positive and negative impacts on employment.

(1) Positive impacts

- Mitigation of climate change requires, for instance, improving energy efficiency. In Europe, millions of jobs are created while energy efficiency is enhanced by 20%. The same would also occur in China.
- Renewable energy policies will create opportunities for green jobs. According to the Eleventh Five-Year Plan for renewable energy, China has set a target to increase the proportion of renewable energy from 5% to 10-15% of total energy consumption in the next ten to 20 years. Developing the hydro power, wind power, biomass and other renewable energy sectors will stimulate employment; in particular jobs in relation to the manufacture, installation and maintenance of energy equipment.
- Financing and investment is required to facilitate energy saving and emissions reductions measures which should stimulate employment in the finance sector. China is one of the main beneficiaries of the international carbon market’s Clean Development Mechanism (CDM) so extra resources in energy projects are expected to boost the development of the energy services sector in China. Jobs in areas such as energy consultation,

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

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

negotiation, auditing, investment and management are currently underdeveloped but yield huge employment potential.

- Sectors with huge potential to take up low carbon technologies and techniques include electricity distribution, transport, construction and the energy intensive industries etc. China is paying more attention to the low carbon economy which will attract large amounts of professionals and workers as these sectors develop.

- There are opportunities for green jobs in the forestry and natural resource management sectors. China has developed several policies for forestry protection and conservation, and the demand for employment in forestry, horticulture, forest management and ecotourism are increasing.

(2) Negative impacts

- The extent that new techniques and environmentally sustainable industries can be developed will depend on the supply of trained technical staff within the labour force. As a developing country, China's labour force lacks the appropriate skill level that such a transformation requires. This puts high pressure on the labour market and limits the employment opportunities for many low-tech workers.

- China's energy saving and emission reductions policy will particularly affect employment in some industries and regions. Many small or medium sized enterprises which are resource-dependant, and energy intensive and that don't meet certain standards will be gradually forced to close down, which will result in structural unemployment. For example, this will especially impact the traditional industrial cities in China's west, and low-skilled workers in the heavy industry, machine manufacturing, iron, coal, construction, vehicle and coal-fired power industry sectors.

  Overall, while policies relating to climate change are expected to have positive effects on employment, they will be limited to the extent that they can be implemented effectively.

2.3 Policies in low carbon development and employment: A global picture

In October 2008, as a response to the global financial crisis, The United Nations Environmental Program (UNEP) put forward the *Global Green New Deal - Green Economy Initiative*[14] This initiative advocates that each country strengthen the green investment component of their economic stimulus package. By promoting environmentally sustainable sectors such as renewable energy, sustainable construction and buildings, eco-agriculture and sustainable transport etc, this initiative aims to change the current pattern of high emissions and energy intensity to one of energy efficiency and environmental sustainability.

Some countries are sold by the potential of an LCE and are actively using a green stimulus to generate green jobs. The Obama administration formulated the *Green Recovery Program*[15], the centerpiece of which is the development of the renewable energy sector to create jobs. It is estimated that for every US$1 billion investment in renewable energy, 20,000 to 30,000 jobs will be created in America annually and 600,000 tons of greenhouse gas emissions will be reduced[16]. According to the University of California, Los Angeles (UCLA), the US renewable energy industry could produce over 1.3 million job opportunities by 2020[17].

European countries have a history of valuing decent work. In 1999, the DGB along with the Enterprise Federation and a collection of environmental NGOs set up the *Alliance for Work and Environment* program. The purpose of the program was to promote environmental protection and expand green job opportunities by way of improvements to building efficiency. From 2001 to 2009, the German government provided nearly US$10 billion in funding for the project and created more than 200,000 jobs. It also realized its target to reduce two million tons of carbon dioxide emissions[18]. In an

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

15 The program planned a $US100 billion investment in green infrastructure over two years, including: energy-saving buildings, mass transport, smart power grid, wind power, solar power, second generation bio-fuels etc. In 2009, the Obama administration issued a $US787 billion investment plan, accounting for 8.7% of GDP. About $US80 billion relates to renewable energy, such as $US20 billion for subsidies and taxes over the next ten years.

16 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 a Global Green New Deal" http://new.unep.org/Documents.Multilingual/Default.asp?DocumentID=562&ArticleID=6079&l=zh&t=long

17 Max Wei, 2009,"The potential for green employment: a US perspective", China Green Jobs Experience Sharing Meeting. 30- 31, March, 2009, Beijing.

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

effort to combat climate change, the economic crisis as well as unemployment, the German government has formulated an economic stimulus package to the value of US$11 billion. The project aims to boost energy efficiency in buildings which is expected to create more than 600,000 jobs. Meanwhile, the package is also expected to reduce Germany's annual carbon dioxide emissions by three million tons.

The Korean government has also formulated a Green New Deal Program valued at US$38 billion and accounting for 1.2% of GDP. The purpose of the program is to provide national catchment area management, public transport networks, information infrastructure, water conservation projects, green cars and clean energy, recycling services, reforestation as well as promote energy efficiency in school buildings and across rural areas. The program is expected to create approximately 500,000 jobs in the areas of water treatment, forestry management and energy efficient buildings.

In March 2009, the European Union announced it would invest €105 billion to finance the development of the green economy to stimulate jobs and economic growth. Japan also declared it would expand its green economy to ¥1.08 trillion by 2015. In China's four trillion stimulus package, around $580 million (14.5% of the total package) will be used as "green" investment.

2.4 China's low carbon strategy

The Chinese government has successively implemented a series of policies and legislative measures to address climate change on the basis of national conditions. Energy saving has been central to enterprise development and has been a policy which has been pushed by the Chinese government since the 1980s. From 1990 to 2005, China's energy intensity declined by 46.6%, equivalent to a reduction in CO2 of 1.8 billion tons. With a coal-based energy supply structure, only 7 to 7.5% of China's energy comes from renewable sources. Currently, China is actively promoting the development of wind power, solar energy, hydro-power, biomass and nuclear energy. In recognizing the potential of investment in forests and eco-system management i.e. carbon sinks, China has increased its investment in afforestation and reforestation.

From 2006, the Chinese government has increased its efforts to promote energy saving and emission reductions under the banner of environmental protection and climate change mitigation. China has developed and adopted several laws, plans and programs including *China's National Program on Climate Change, the Medium to Long Term Development Plan for Renewable Energy*, the *Eleventh Five-Year Plan for Renewable Energy*, and the *Energy Saving Law and the Renewable Energy Law*. Other relevant laws such as the *Recycling Industries Promotion Law* and *Energy Law* will be implemented soon.

At the National Energy Saving and Emissions Reduction meeting in May 2007, the Chinese Premier Wen Jiabao presented the main measures to save energy and reduce emissions. These were:

(1) To limit the rapid development of industries such as electricity, iron and steel, nonferrous metals, building materials, and petroleum and chemical processing which are resource and energy intensive and have high emissions and pollutants

(2) To eliminate outdated production capacity in the power iron and steel, nonferrous metals, building materials, electrolytic aluminium, ferroalloys, coal, coke, paper and food industries;

(3) To popularize the use of energy saving products;

(4) To develop the recycling industries including the use of mineral resources and hard rubbish, and the recycling of renewable resources and water;

(5) To improve the institutional environment and policy systems that inhibit energy saving and emissions reductions;

(6) To increase the financial inputs from government, enterprises and society as a whole.

The above measures set the priorities for the transformation of the industrial structure and the pattern of economic growth, and will have big impacts on employment in industries such as power, iron and steel and renewable energy.

China has made great progress in implementing energy saving and emissions reduction measures. During 2006 to 2008, energy consumption per unit of GDP decreased by 10.08%. The process of structural transformation and technology advancement is expected to produce favorable effects on employment.

2.5 Key industries related to low carbon development

The United Nations Environment Program (UNEP) and the International Labour Organization (ILO) released a report entitled *Green Jobs: Towards Decent Work in a Sustainable, Low Carbon World.* This report outlined six sectors that have the potential to achieve lower greenhouse gas emissions, resource conservation and job promotion. These key sectors which include renewable energy, building and construction, transportation, basic industry, agriculture, and forestry, show the greatest potential for reducing greenhouse gas emissions and increasing green employment. Forestation, renewable energy, transport, green buildings and recycling harbour the greatest capacity for job creation.

1. Forestry

Forests are the largest carbon sinks and the most economical absorbers of carbon. According to the 2007-2008 Human Development Report by 2005, the total carbon sink volume of China's forests was about 6.10 billion tons, or 2.16% of the world's total carbon sinks volume. From 1980, the Chinese government made huge financial investments into forest development and launched a series of key forestry projects as a way to expand the size of China's forest cover. As a result, the size of China's forest carbon sinks expanded considerably. In 2007, China published its National Climate Change Program, stressing the value of afforestation and reforestation to maximize forestry carbon sinks as an important measure to address climate change. It is estimated that during the period 1980 to 2005, China's investment in afforestation enabled the country to absorb 3.06 billion tons of carbon dioxide. According the to China Forestry Development Strategy, by the year 2050, China's forest coverage rate will increase to 26% of its total geographical area and the total carbon sink volume of China's forest reserves will increase to 90.4% of 1990 levels.

Forestry-related industries span the agricultural, industrial and tertiary sectors. The potential for employment in the forestry sector will lie in the following industries: (1) in forestry by-products: this includes timber manufacturing and processing and the agro-forestry industries such as flower, bamboo, food and medicines etc; (2) afforestation: six major projects on afforestation or reforestation are expected to generate millions of jobs over the next ten years through an increase of 76 million hectares; and (3) forestry Tourism: China's eco-tourism and forest tourism witnessed rapid development and an increase in activity by 30%.

2. Energy Sector

Constrained by the government's initiatives on energy saving and emissions reductions, the employment outlook for the energy sector varies greatly depending on the segment. Employment in the traditional fossil fuels segment such as thermal power generation is likely to be negatively impacted, while employment in the new-tech industries such as renewable energy, carbon capture and storage may directly promote new jobs .

The power generation industry provides an example of the differing impacts on the sector.

(1) Thermal power generation: This sector is undergoing reform and is being encouraged to invest in energy efficient measures in the context of shifting to low carbon development. As a result, the closing down of small energy inefficient, environmentally unsound coal-fired power plants increase the economic efficiency of the sector at the expense of jobs.

(2) Hydropower, wind and solar power: Of these three low carbon energy sectors, wind and solar power plants will not be able to absorb significant amounts of labour directly but can potentially create job opportunities in downstream and upstream sectors such as equipment manufacturing and technical services.

(3) Biomass Energy: This type of energy relates to the development and research of biogas, firewood, bio-fuels, straw processing and recycling, biomass power generation and power generation equipment manufacturing. Related to different industry chains, these segments have considerable potential for job creation.

(4) Nuclear Power: This low carbon energy sector has the potential to produce direct and indirect employment effects.

3. Iron and Steel Industry

The iron and steel industry is typically high-polluting, energy intensive and a large emitter of greenhouse gases. Efforts towards a more carbon friendly iron and steel industry will bring negative impacts to employment.

China is the largest producer and exporter of iron and steel in the world. In January 2009, China's National Iron and *Steel Revitalization Program* stressed the need to push the sector towards low carbon development by controlling the total number of plants, closing down small-scale inefficient plants and consolidating and reorganizing existing plants. The implementation of energy saving and emissions reductions measures will impact on employment in two ways. One, a reduction in employment from curbing the expansion of the traditional iron and steel industry; and two, new job creation through the introduction of advanced technology. Increasing productivity via advanced technology will also push forward the development of services related to the sector and create new jobs.

4. Recycling Industry

Resource recycling is an important part of the recycling economy. The recycling economy involves the reuse, recovery and recycling of energy and resources. As early as the 1980s, China has been implementing a comprehensive resource management program and the utilization rate of industrial wastes (gas, water and solid waste) has increased to over 60%[19]. Despite this, renewable resource recycling remains an immature industry in China and resource productivity is only at 10%. Considering the huge disparity in technological levels and resource consumption between enterprises and the increasing shortage of resources, resource reuse is considered to be the most important factor in firmly establishing the recycling economy and achieving low carbon development.

In a report on a series of pilot projects in recycling published in 2005, the recycling and recovery schemes for scrap metals, plastics, paper, and electronic waste featured prominently. It is widely believed that China's resource recycling market is a promising area which may yield very significant employment opportunities, either direct or indirect. According to estimates, in 2006, China's total volume of recycled waste amounted to 158.1 million tons, 40 million of which was imported from other countries. The gross value of domestic resource processing in the same year totaled RMB 350 billion, a 22% increase from 2005. In 2008, 20% of non-ferrous metals produced were recyclable. All over the world, waste recycling and management are made up of a chain of industrial players across the tertiary and manufacturing sectors. Currently, China's waste recycling services sectors are estimated to employ more than ten million people, six million being migrant workers engaged in temporary roles with indecent work conditions. This situation poses two problems: firstly, temporary workers lack job security and also are not provided with health and safety equipment needed to do their work; secondly, the manual nature of the recycling sector leads to poor waste recycling practices and environment degradation. It is imperative that temporary workers receive training and that supportive government policies are put in place to promote the professionalization of the waste management and recycling services sector[20].

[19] China Resource Recycling Association, "Promoting industrial energy saving and comprehensive utilization by implementing recycling economy".

http://www.crra.org.cn/listDetail.aspx?INAC_PID=INACID20080902150814 1347&INAR_ID=ARID20090123101 2077368&INAC_ID=INACID20080908175330 4182

[20] 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 so on.

3. Methodology and Data

3.1 Research Framework

This research primarily focuses on the impact of low carbon development policies (including energy saving and emissions reduction, renewable energy and eco-forestry projects) implemented in the forestry, energy, iron and steel sectors and the green investment component of China's economic stimulus package. The research was carried out in two separate phases. The first phase focused on the thermal power generation and carbon sink forestry sectors; the second phase focused on the wind and solar power, iron and steel, forest tourism and green investment sectors. The basic framework of the research is as follows:

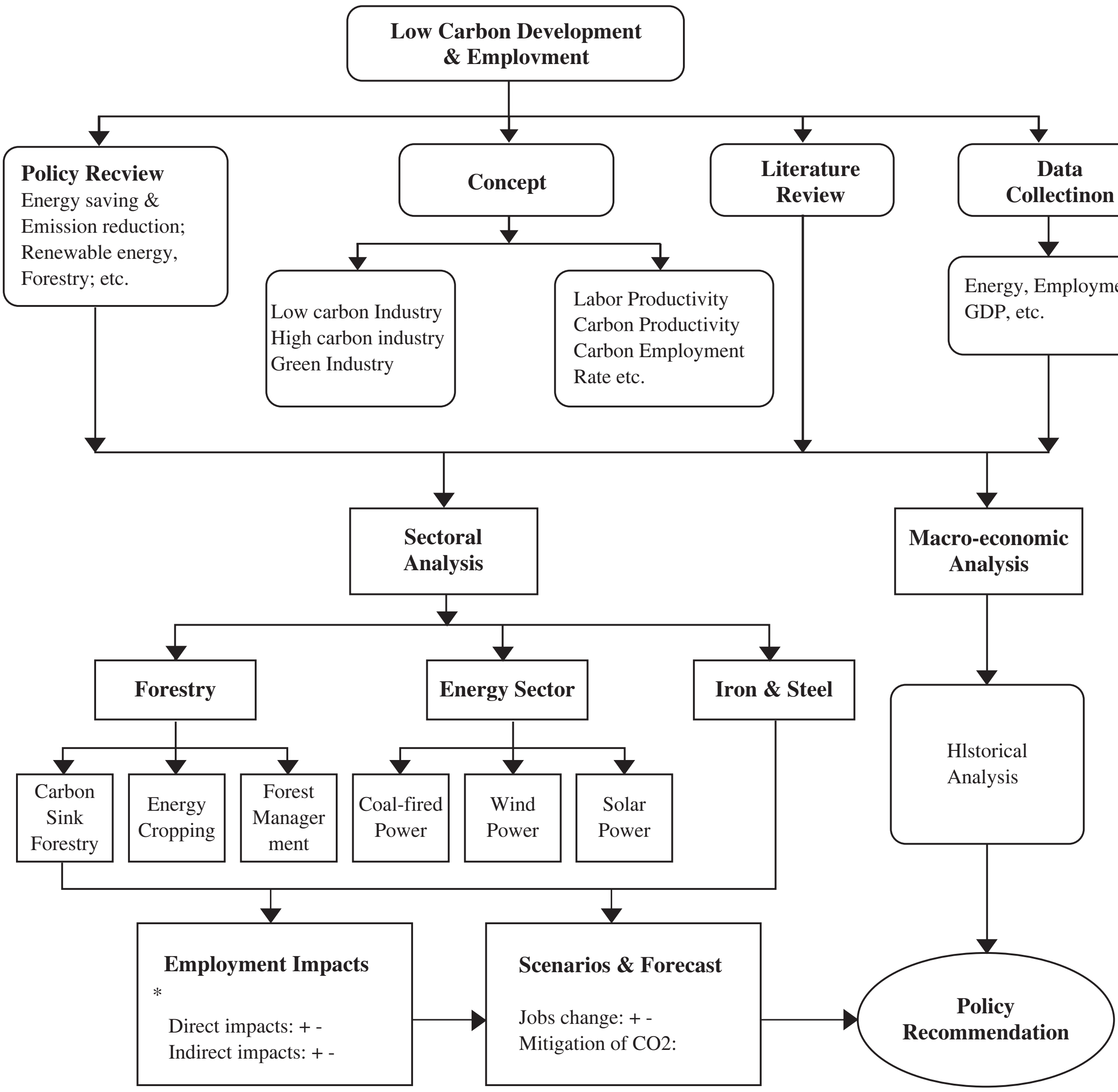

Figure 1-1: Analytical Framework

3.2 Analytical Methods

Based on literature reviews, the impact of low carbon development on employment can be approached in two ways. One is a top-down approach by way of input-output analysis and historical trend analysis using econometric tools. The other method uses a bottom-up approach where data is collected by way of enterprise interviews and by conducting field investigations.

The impacts on employment were measured by conducting industry case studies to ensure the reliability of statistical analysis, utilizing the two above-mentioned approaches, and reviews of international and domestic literature. The effect on employment was addressed in three levels. The first level focuses on the direct effects on employment which relate to increased investment driven by specific environmental policies e.g. the application of new technology or new investment in renewable energies etc. The second level looks at the indirect effect on employment relating to an increase in the input of goods from suppliers in that sector, with a rippling effect through the supply chain. On the third level, induced employment resulting from these supply chain effects and an increase in income in the economy is determined i.e. employment related to the spending of increased income which has flow-on impacts for the whole economy.

4. Macro-analysis of Low Carbon Development and Employment in Major Sectors

Based on the availability of data, this study approaches research topics in the following fields: (1) agriculture (farming, forestry, animal husbandry, sideline industries and fisheries); (2) mining; (3) manufacturing; (4) electricity, heat, gas and water production and supply; (5) construction; (6) transport, storage and telecommunications; (7) wholesale, retail, dining and accommodation; and (8) other services[21]. This study intends to differentiate low carbon industry from high carbon industry by analyzing carbon productivity, energy intensity and the carbon employment rate and suggest feasible policies and objectives by examining the differential impacts on low carbonization in each industry sector.

4.1 Historical trends in employment, output and energy consumption in major sectors

1. Employment and output changes in China's major sectors

The total population of China engaged in economic activities rose from 101 million in the early 1950s to 780 million in 2007. During this period, there were notable changes to the structure of China's job market amid rapid urbanization and industrialization. Of great significance has been the drop in the proportion of the labour force engaged in agriculture, from 80% in the 1950s to 40.8% now. Meanwhile, the proportion of the labour force engaged in the industrial and tertiary sectors has risen from 7.4% and 9.1% in 1952, to 26.8% and 32.4% in 2007. In 1994, the proportion of the labour force employed in the tertiary sector surpassed that of industry, showing robust growth (refer to figure 1-2).

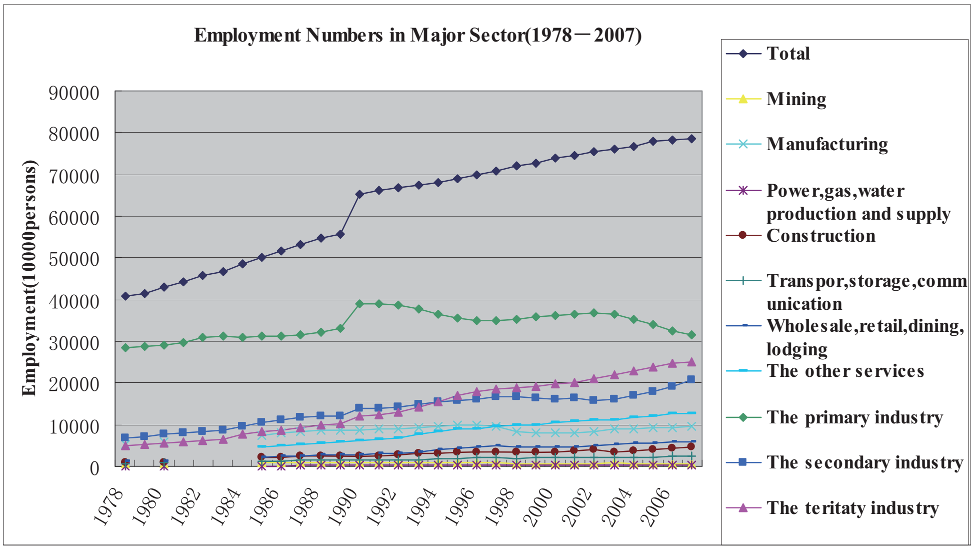

Figure 1-2: Employment in China by Sector, 1978- 2007

During the same period, the output of each sector has also been changing. As shown in Figure 1-2 and Figure 1-3, the proportion of output to employment in each sector shows a very different picture.

[21] Note: Other services include finance; real estate; information technology and software services; tenancy and business; scientific research and technical services; water conservation, environmental protection and public infrastructures; residential services; education, culture, sports and entertainment; sanitation; social security and welfare; public management and social organizations. There are two types of services in tertiary industry, one is producer services and the other is consumer services. Producer services are dependent on the manufacturing industries and provide human capital and knowledge as inputs for the manufacturing process. China's "Eleventh Five-Year Plan" proposed to develop the following six major producer services: modern logistics, international trade, information services, finance and insurance, convention and exhibition and intermediary services.

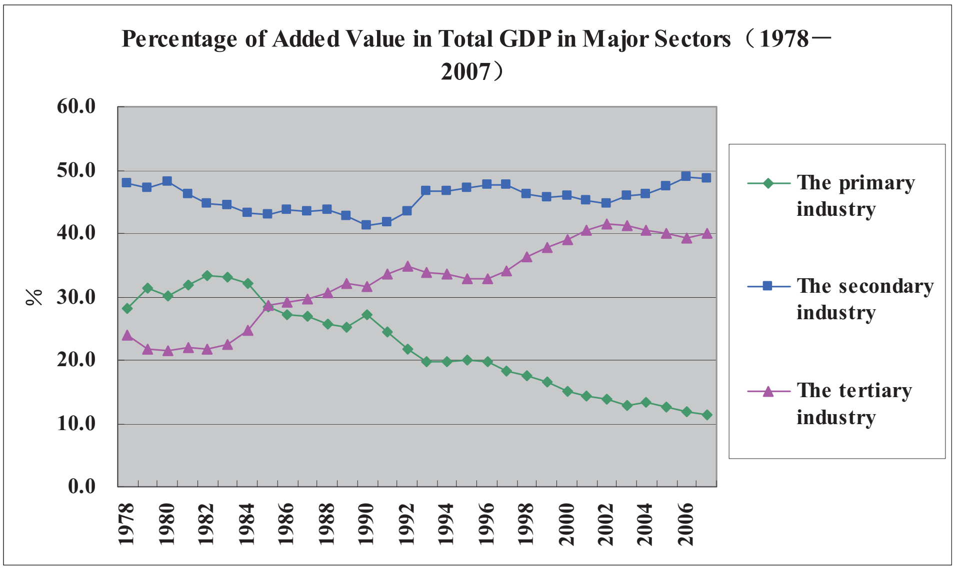

Figure 1-3: Percentage of added value to GDP in three major sectors 1978-2007

Figure 1-3 shows the changes to added value within the three major sectors. As industrial output forms an overwhelmingly high proportion of China's GDP, this reflects that China is still in the mid to late stages of industrialization. The proportion employed in agriculture in comparison to output of the sector has been steadily decreasing each year. The proportion employed in secondary industry has fallen below 30%, while output remains half of the national total. The tertiary sector began overtaking agriculture in the mid-1980s and output has maintained a steady increase since. Currently, tertiary sector output remains at 40%. Throughout the process of industrialization and urbanization, the structure of China's economy has undergone a shift from production-oriented to service-oriented. Apart from the rapid growth of services such as finance, insurance and real estate and consumer services like tourism, retail, culture and recreation etc have sprung up in step with the rising standards of living of the Chinese people.

2. Labour productivity by sector

As seen in Figure 1-4, apart from Other services, the labour productivity of most industries has risen over the past three decades. Basic industry had the largest rate of increase during this time, which, mostly due to the capital-intensive nature of the industry and advancements in technology, had productivity nine times higher in 2007 than in 1985. Lower productivity in the service industry points to the sector's need to increase the proportion of output from high-end services such as technological development, finance and insurance, consultation, culture and entertainment etc.

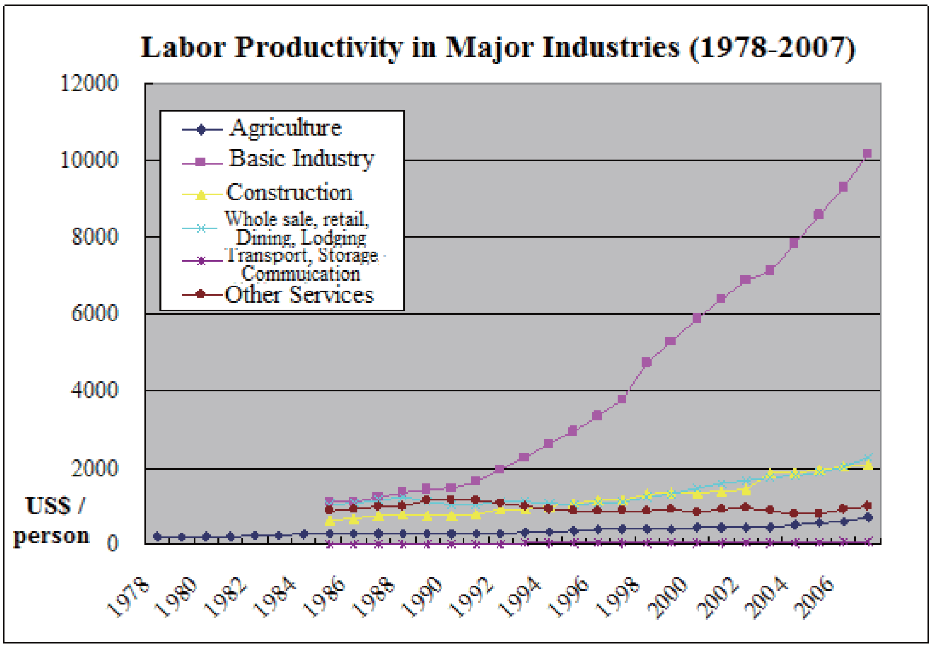

Figure 1-4: Labour productivity in major sectors 1978-2007

3. Energy consumption of different sectors

As seen in Figure 1-5, energy consumption has increased steadily since the 1980s, particularly from 2002. This is due to the increase in the proportion of heavy industry in China's industrial sector raising the demand for energy. As a result, basic industry became the largest consumer of energy compared to the other economic sectors and also the largest pollutant and carbon emitter.

Compared to the energy consumption of other sectors, basic industry accounts for more than 70% of energy consumed, among which over 80% comes from manufacturing. However, there is one important difference in energy consumption between China and developed countries. In developed countries the majority of energy consumed is concentrated in the building and construction and transport sectors, while in China, energy consumption is mainly in industry. Residential consumption is relatively low. For example, energy consumption in industry is only 20% in the US and 30% in Japan. This supports the notion that China is indeed a "world factory" characterized by high energy consumption.

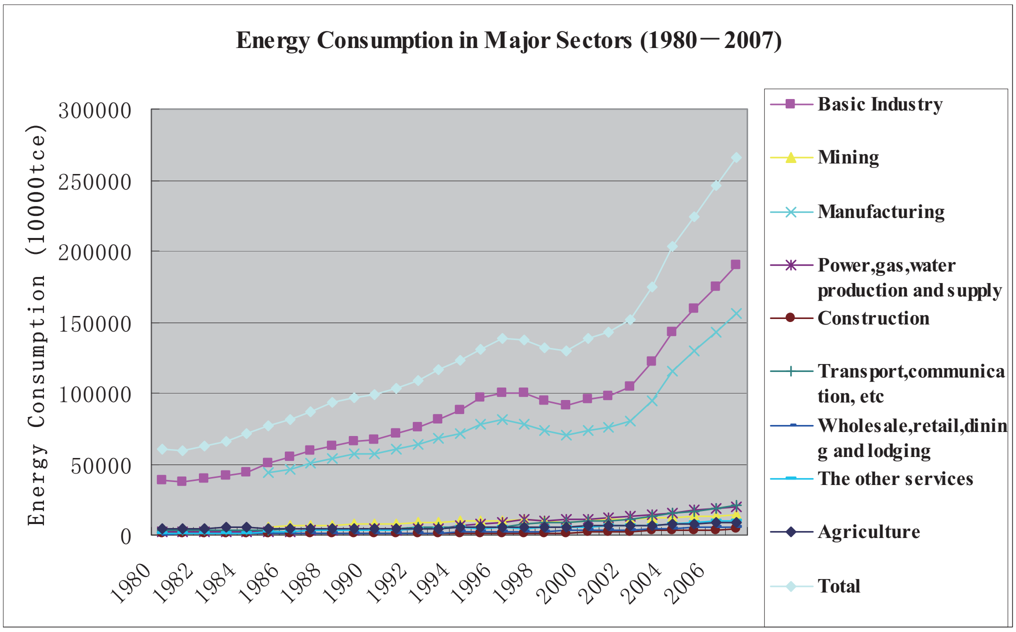

Figure 1-5: Energy consumption in major sectors 1970-2007

4.2 Comparative analysis of the carbon productivity and carbon employment rate in major sectors

Generally speaking, four essential elements are required for economic development: capital, labour, energy and technology. Many studies have explored in depth the differing impacts that energy, capital and labour have on economic growth. Studies show that the relationship between energy, capital and labour is either complimentary or based on substitution.[22 23 24]. Policy implications lie in the fact that if a relationship of substitution exists between the energy and non-energy element i.e. capital and labour, then the sector can maintain normal economic growth by making the best use of capital and labour should the price of energy go up or energy saving and emissions reduction strategies be implemented. On the other hand, should there be a complementary relationship between the energy element and non-energy element, then in the short term, the rising opportunity cost of energy caused by stricter environmental policies and regulations may drive down investment in energy and other inputs such as labour and capital, thus decreasing the output of this sector and the demand for jobs. However, in the long term, the deployment of new technology and efficient equipment will reduce the costs of energy and improve the economic output. This may, in turn, reduce the cost of other inputs such as labour per unit of energy.

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

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

[24] 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

Based on the above analysis of the comparative study between the carbon productivity and carbon employment rates and the relative changes in the relationships between employment, output and energy consumption in the major sectors, interrelationships among indicators reveal the possible effects of energy saving and emissions reduction (ESER) policies on energy consumption, output and employment in major sectors.

1. China's low carbon development trend

Figure 1-6 reflects the changing pattern of China's carbon productivity. In general, China has been on the path towards low carbon development, although from 2002 there was an unfavorable change in China's economic structure and energy efficiency. However, after the introduction of China's *Energy Saving* and *Emission Reduction Strategy* in 2005, the downward trend in carbon productivity started to reverse, reflecting the positive impact of energy-saving strategies on economic output per unit of carbon emissions.

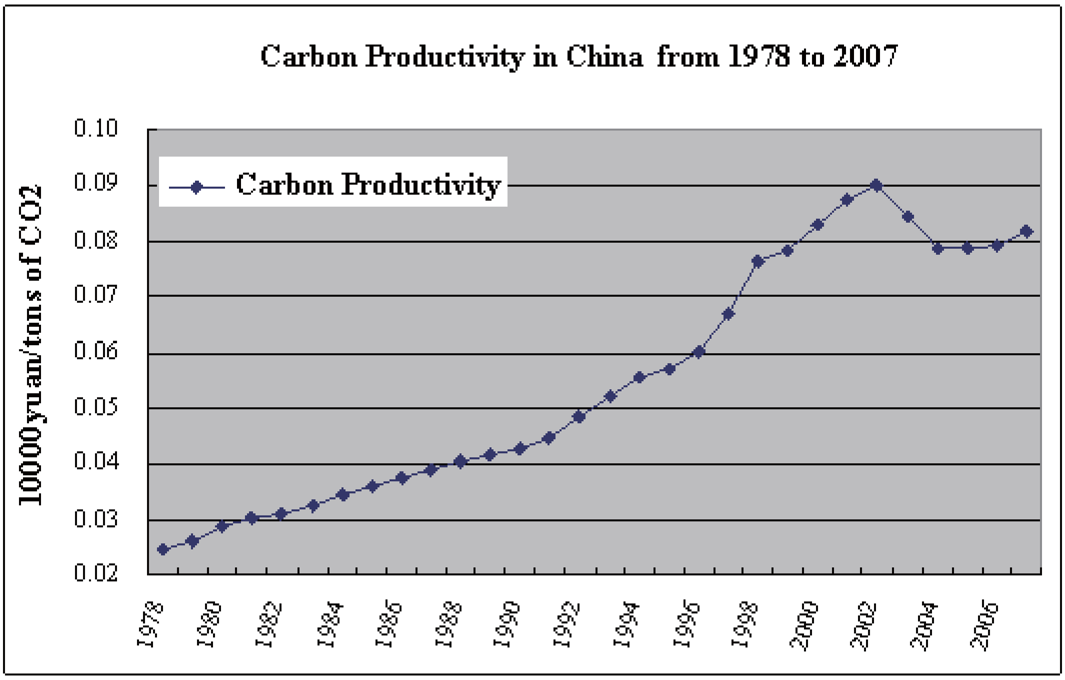

Figure 1-6: China's carbon productivity 1978-2007

Different industries' reliance on energy varies due to specific industry characteristics and technology levels. Figure 1-6 shows carbon productivity by way of the output variance of per ton of CO_2 emissions among industries. China's energy intensity has been decreasing since the 1980s, particularly in the industrial sector, where energy intensity has decreased threefold over the past 20 years. The next two sectors which have seen the biggest decrease in energy intensity are transport and building and construction. Studies show that during the period 1980 to 1990, the dramatic decrease in China's energy intensity was the result of improvements to energy efficiency resulting from technological advancement, enterprise restructuring and increased management effectiveness and the optimization of energy in the economy. However, from 2003, this trend started to flatten out and actually reversed to some extent. This was brought about by an increase in the development of heavy industry, mainly the high energy intensity sectors of automobiles, cement and electrolytic aluminium which caused energy consumption to outgrow economic growth for the same period. This, in turn, caused a decrease in carbon productivity.[25]

[25] Shi Bo, "Energy consumption, Structural changes and China's Economic Growth:1952-2005", Contemporary

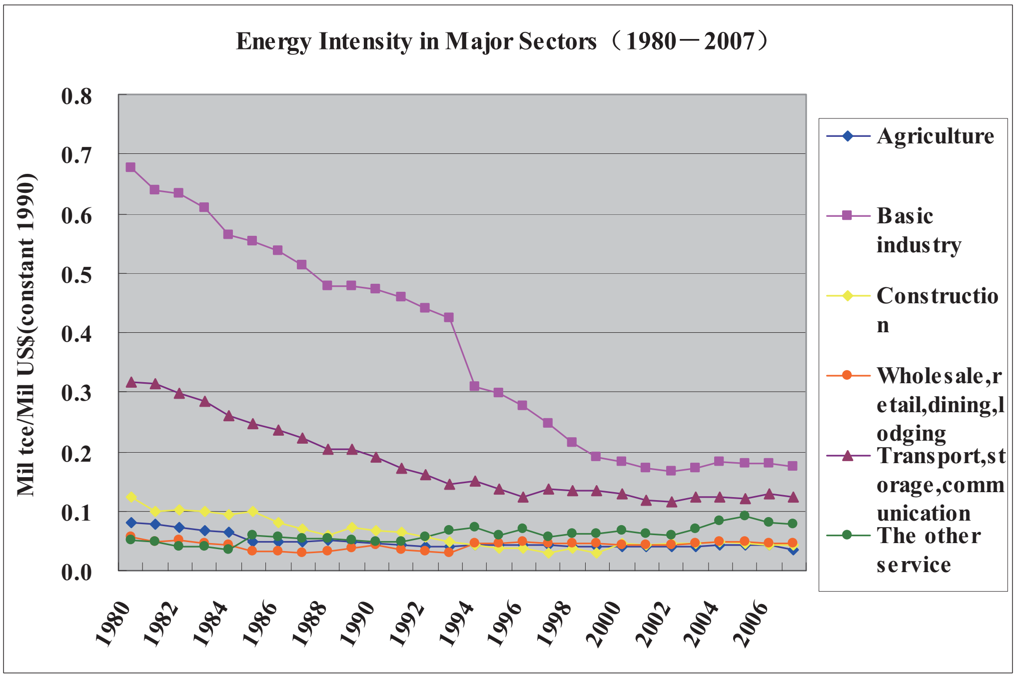

Figure 1-7: Energy intensity of major sectors 1980-2007

2. Comparison of the carbon-employment rate in major sectors

The following table shows the indicator, Carbon Emission-Employment Rate (or Carbon-Employment Rate or EER. For EER function refer to Annex 2), which analyses the relationship between employment and energy consumption in a specific industry.

Industry	Carbon-employment rate (jobs/tons of CO2)
Total	**0.56**
Primary Industry (agriculture, forestry, cattle fisheries etc)	**28.58**
Secondary Industry	**0.14**
Basic Industry	0.08
Mining	0.08
Manufacturing	0.15
Power, gas, water production and supply	0.01
Building and Construction	12.25
Tertiary Industry	**15.67**
Transportation, storage and postal services	4.02
Wholesale, retail, accommodation and dining	11.26
Others	27.77

Table 2-2: Carbon-employment rate in major sectors (2005)

It can be seen from the table that the EER of primary and tertiary industry is much higher than secondary industry. This indicates that the incremental carbon emissions are lower in primary and tertiary industry than for the same incremental increase in employment. Furthermore, in the tertiary industry, the EER in consumer services is mostly higher than that of production services. For example, a one ton increment of CO_2 can produce four transportation sector jobs while creating 11.26 jobs in the wholesale, retail, accommodation and dining sectors and 27.77 jobs in other services.

4.3 Conclusions

Over the past few decades, China has been on track to low carbon development through lower carbon emissions and increasing carbon productivity. This has been the result of advancements in technology and decreasing energy intensity.

In terms of emission levels, basic industry and manufacturing are the sectors generating the highest amounts of emissions. Using the carbon employment rate indicator, the primary industry and tertiary industries, e.g. the agriculture, forestry, services, wholesale and retail, accommodation and catering sectors etc can create ten to 28 jobs for each ton of CO_2 produced. Fewer jobs per unit of emissions can be generated in sectors in basic industry, such as manufacturing, mining, power generation and supply. Therefore, using the two indicators of carbon productivity and carbon employment rate, the primary industry and tertiary industries have potential advantages for achieving low carbon development in China. Promotion of the tertiary industry, in particular the manufacturing and consumption-based services sectors, would not only stimulate economic growth through more social services, but also create new jobs with fewer emissions, contributing to the achievement of the dual objectives of employment and low carbon development. In addition, support should be given to primary industry sectors with high carbon productivity (such as eco-forestry, agriculture and sideline industries) and use energy-saving and emissions reductions to promote low carbon development in secondary industry. This will promote the optimization of China's economic structure optimization and increase carbon productivity.

In terms of industry, secondary industry has higher emissions than the primary industry and tertiary industries due to the stage of development it is currently in. As important pillars of the economy, high emissions industries such as mining, manufacturing, power, and transportation must provide material inputs for all of society. As China is in the mid to late stages of industrialization, it is difficult to make radical changes to the structure of the economy in the short term. Therefore, to achieve low carbon development, China should introduce energy saving and emissions reductions policies in industry; foster technological improvements and increased management efficiency in enterprise; and promote reductions in energy intensity and increased carbon productivity in high consumption industries. Developing technological support services for the basic and consumption-oriented services industries will also promote job generation on the basis of low energy consumption.

PART II. Employment Impacts in Major Sectors

1. Forestry Sector[26]

1.1 The impacts of climate change on the forestry industry

The development of the forestry industry and China's overall ecological environment are important means to address climate change and achieve low carbon development. The Chinese government considers natural resource management as a foundation and important entry point in achieving sustainable development and has firmly anchored the forestry industry at the centre of its strategy for economic and social development.

The impacts of climate change will also be felt by forestry resources which will have corresponding effects on forestry sector employment.

The positive impacts of climate change on the forestry sector include:

(1) Increased government investment in forestry eco-projects which spurs forestry sector employment;

(2) The emergence of new low carbon industries such as carbon sequestration, forestry biomass, forestry products, eco-tourism, forestry sustainable management etc. These industries will extend the forestry industrial chain and create new employment opportunities.

The negative impacts include:

(1) Restrictions to the development of the wood logging and processing industry and forestry products processing industries resulting in lay-offs for large numbers of workers;

(2) Changes to the distribution of forests leading to natural disasters such as droughts, floods and the increased prevalence of pests and diseases which carry repercussions for forestry sector employment

Forestry is an entire industry chain in itself, made up of primary, secondary and tertiary industries. Table 2-1 shows the carbon emission and employment potential of traditional and newly emerging sectors within the forestry industry. The table shows that the development of the forestry industry will slow down or mitigate the effects of climate change as well as create opportunities for green employment. Actively developing the forestry processing and manufacturing, forest by-product and eco-tourism sectors will beis favorable for promoting China's transition to low carbon employment.

Industry sectors			**Environmental impact**	**Contribution to climate change**	**Opportunities for job creation**
Traditional Forestry Industries	Forestry cultivation, plantation and conservation	Forest cultivation	Increase carbon sinks	Positive	Strong
		Forest plantation	Increase carbon sinks	Positive	Strong
		Forestry conservation	Increase carbon sinks	Positive	Strong
	Forest harvesting and transportation	Forestry harvesting	Produce carbon emissions	Negative	Weak
		Forestry transportation	Produce carbon emissions	Negative	Weak
	Processing and manufacturing of forestry products		Produce carbon emissions	Negative	Medium
	Plantation and gathering of non-timber forestry products		Increase carbon sinks	Positive	Strong
	Plants and Flowers		Increase carbon sinks	Positive	Strong
	Bamboo		Increase carbon sinks	Positive	Strong

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

Newly Emerging Forestry Industries	Forest tourism, recreation and culture	Forest tourism	Low carbon emissions	Neutral	Strong
		Forest leisure	Low carbon emissions	Neutral	Medium
		Forest culture	Low carbon emissions	Neutral	Medium
	Non-wood products		Low carbon Emissions	Neutral	Strong
	Forestry eco- services	Forestry carbon sinks	Increase carbon sinks	Positive	Medium
		Forest hydro- services	Increase carbon sinks	Positive	Medium
		Biodiversity protection	Carbon sequestration	Positive	Medium
		Other forest eco-services	Increase carbon sinks	Positive	Medium
	Forestry bio-industry	Bio-energy resources	Carbon substitution	Positive	Strong
		Bio-materials	Carbon substitution	Positive	Strong
		Bio-pharmaceutical industry	Carbon substitution	Positive	Strong
		Green chemicals	Carbon substitution	Positive	Strong
		Green food	Carbon substitution	Positive	Strong

Table 2-1: Carbon emissions and capacity for job creation within the forestry industry

1.2 Methods for promoting low carbon development in the forestry industry

The forestry industry can make a positive contribution to low carbon development in China. Afforestation, reforestation, forestry management, wetland protection and fossil fuel substitution are effective means to not only mitigate the greenhouse effect and absorb carbon dioxide emissions but also stimulate the creation of green jobs (Jia Zhibang, 2008).

The main channels for promotion of low carbon development in the forestry industry include forestry carbon sinks, carbon storage and carbon substitution (Figure 2-1). Among these channels, carbon forestry and energy cropping hold broad development prospects and will play a positive role in instigating low carbon development and promoting green employment.

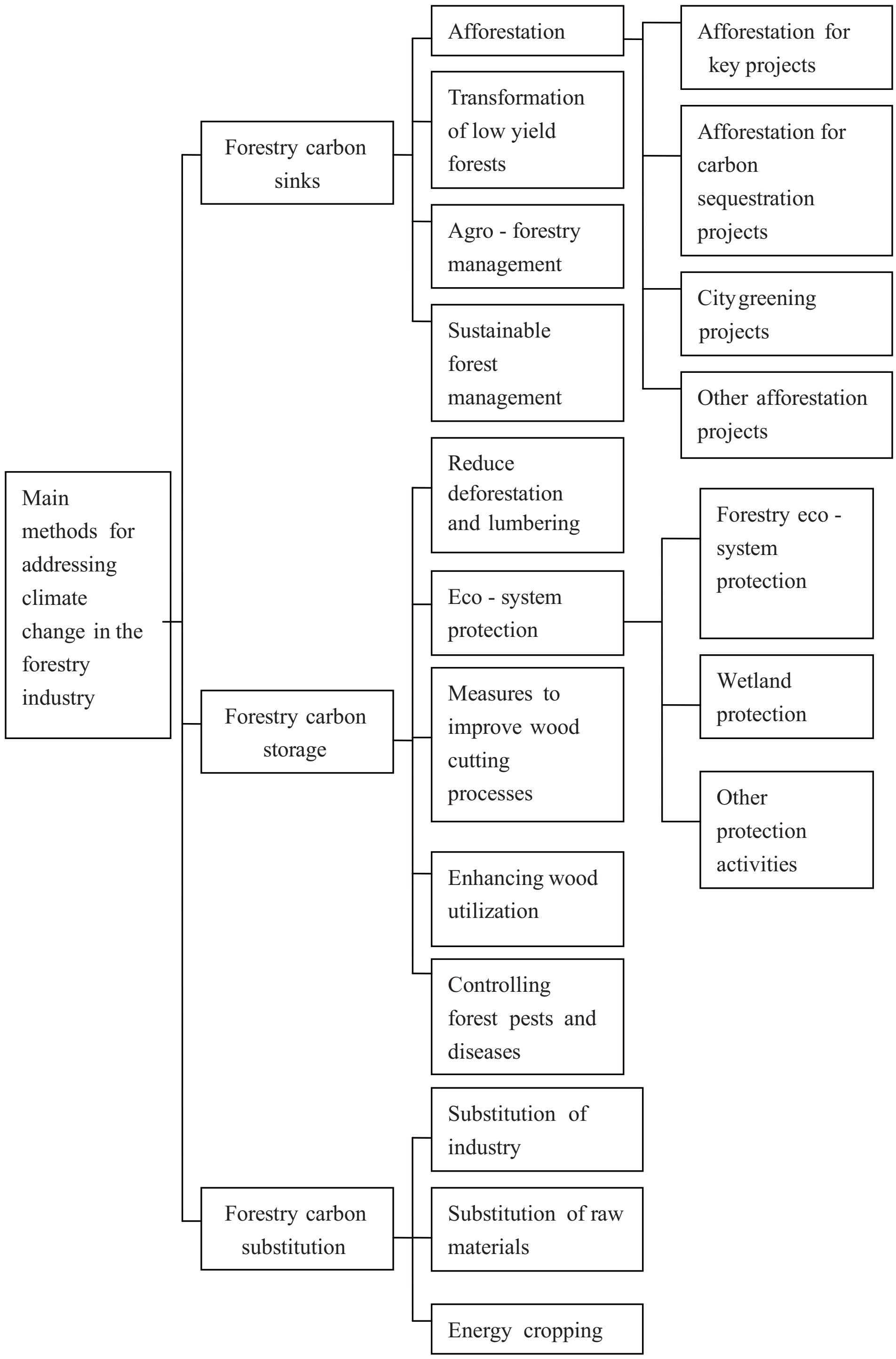

Figure 2-1: Analytical framework of forestry and low carbon development

1.2.1 Carbon-sink forestry

In general, carbon-sink forestry includes both carbon sinks and storage. Carbon-sink forestry aims to lower the concentration of carbon dioxide in the atmosphere and mitigate climate change. As the cost of carbon dioxide absorption via afforestation and forestry protection is much lower than the cost reducing emissions generated by industry, afforestation and reforestation are one of the most economical and effective measures to address greenhouse gas emissions.

Forestry carbon storage is necessary to reduce carbon emissions by preserving and maintaining present levels of carbon stored in forests. Through sustainable forest management, a series of carbon management measures are adopted to reduce carbon emissions and increase carbon sequestration so to gain the full benefit of carbon sinks. Measures include eco-system conservation, reducing deforestation, improving logging measures, enhancing wood utilization and more effective management of natural disasters (forest fires and the spread of plant diseases and pests).

China is fully aware of the important role that afforestation and conservation play in addressing climate change, increasing carbon sinks and generating employment. China's State Forestry Administration has incorporated developing carbon sinks into the overall forestry development strategy and has started several afforestation and re-afforestation projects. While not all afforestation projects can be brought into CDM projects[27], potential international carbon market demand will provide good opportunities for carbon-sink forestry and employment in China. (The distribution of carbon sink projects in China is demonstrated in Figure 2-2). [28]

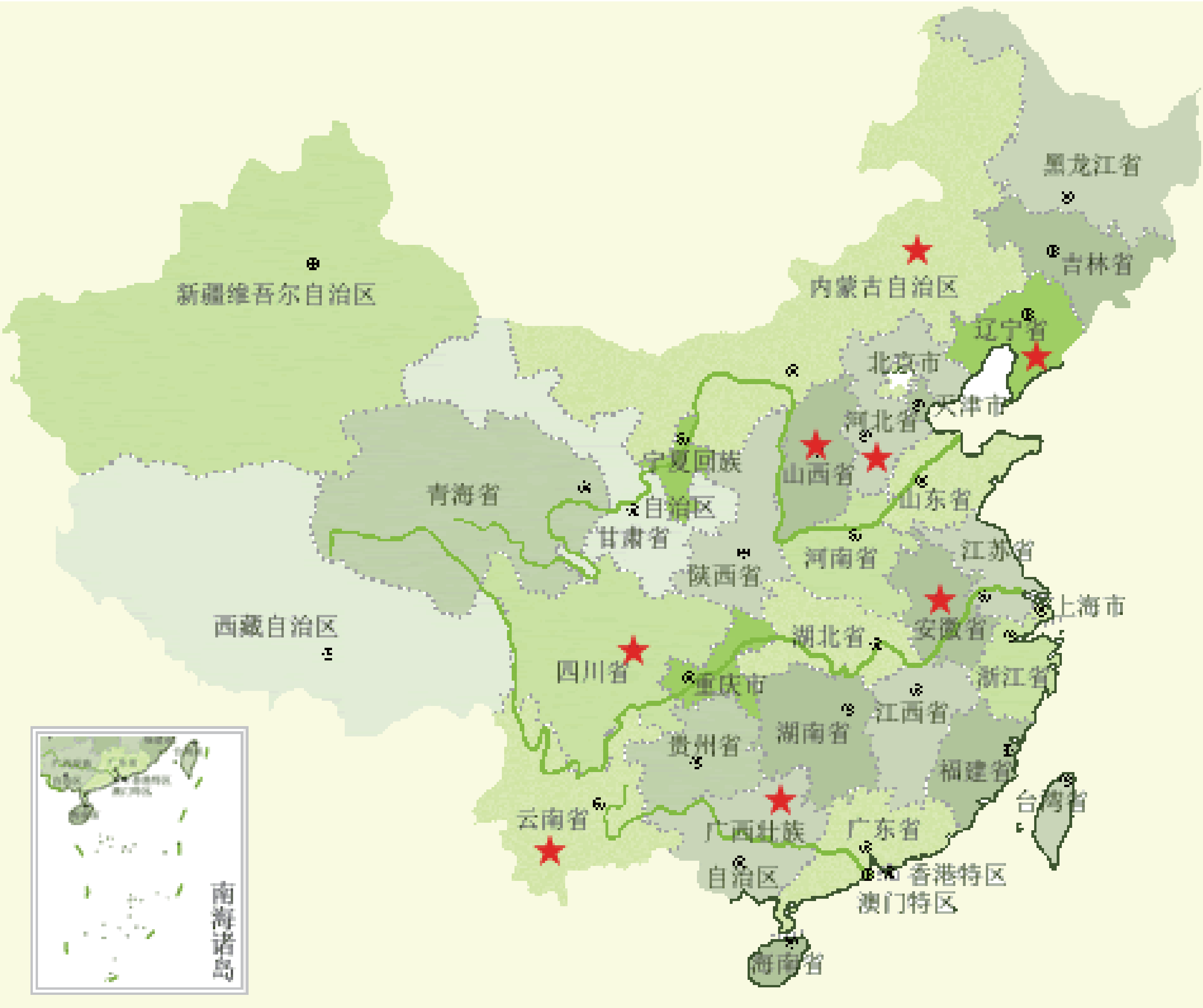

Figure 2-2: The distribution of forestry carbon sink projects in China

1.2.2 Energy cropping

Energy forestry, also known as energy cropping, is a method of carbon substitution which aims to develop biomass energy instead of fossil fuels, durable wood products instead of energy-intensive materials, and use renewable wood

27 Generally speaking, afforestation under CDM refers to plantation on land which has not been used for forestry for a long period of time. The UNFCCC (2001) Marrakesh Accord defines afforestation as "the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources "(UNFCCC, 2001a). Reforrestation refers to the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land.

28 In 2004, the 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 the Kyoto Protocol were applied in Guangxi and Inner Mongolia.

fuel (such as energy plantations) and logging residue. To avoid occupying agricultural land, energy cropping presently makes use of barren mountains, wasteland and sandy areas suitable for forestry as well as saline and alkaline lands unsuitable for cultivating..

Forestry biomass is a diverse sector in China, which provides great potential for energy cropping. According to the *Development Plan for National Energy Forestry* promulgated by the State Forestry Administration, China will establish 667,000 hectares of base energy forestry during the Eleventh Five-year-plan and by 2020, energy forestry will reach 13.34 million hectares. This is enough to generate six million tons biodiesel and meet the fuel needs of power plants of over 11 million kilowatts.

In addition, the forestry sector can still meet low carbon development objectives through raw material and industry substitution. Raw material substitution is the substitution of energy-intensive materials i.e. iron, cement, aluminium products, plastic and tiles etc with durable wood products. This has the result of decreasing greenhouse gas emissions produced by burning fossil fuels in the process of producing energy-intensive materials. Industry substitution refers to using forestry as a basic production unit, which can provide forestry resources and products and create many emerging low carbon industries such as forestry cultivation, forestry mangement and protection, eco–tourism and the forest bio-industry etc. This will have the effect of reducing carbon emissions and protecting the environment while improving the industrial structure and increasing green employment.

1.3 Afforestation and reforestation

1.3.1 Afforestation in China

The Kyoto Protocol, adopted in 1997, made a commitment to reducing and limiting levels of greenhouse gas emissions based on 1990 levels by absorbing carbon dioxide emissions through afforestation, reafforestation and forestry management. Forestry activities have become one of the most economical and effective measures for countries to reduce and limit emissions. The maximum potential for global carbon sequestration in 2000 to 2005 was estimated at 1.53 to 2.47 billion tons of carbon per year, with 28% contributed by afforestation, 14% from reafforestation and 7% from agro-forestry[29].

China has been carrying out afforestation and reforestation projects to improve natural resource management and combat global warming. Since the 1990s, China has successively launched ten key forestry projects spanning 97% of China’s counties with afforestation and reforestation planned for over 7.34 million hectares. The Sixth National Forest Inventory (1999-2003) reported that China’s forest coverage is 18.21%, fifth in the world in terms of area, and sixth in the world in terms of forestry reserves. *The National Climate Change Program* indicates that during 1980 to 2005, the cumulative net sequestration of carbon dioxide in China’s was 3.06 billion tons from afforestation, 1.62 billion tons from forest management and 0.43 billion tons from deforestation prevention.

[29] Jiang Zehui, 2003, "Climate change and forestry eco-construction in China", "Papers collected for the climate change and eco-environment seminar”.

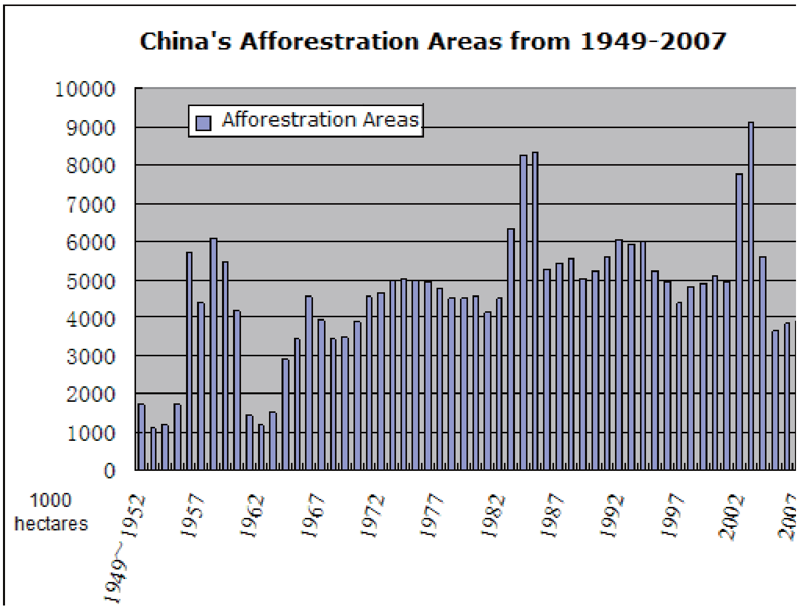

Figure 2-3: Area of national afforestation 1949-2007[30]

Afforestation has the following characteristics:

(1) As a labour intensive activity, it has the potential to engage large numbers of workers;

(2) "Green" in nature, afforestation can contribute to the development of the low carbon economy and benefit the environment through carbon-sinks;

(3) The work is seasonal (mainly in spring) and employment is usually temporary;

(4) Connected to a wide range of activities, it is an indirect force in driving employment in related industries. A typical afforestation project includes project planning, on-site clearing-up, land ploughing, seedling preparation, tree-planting and post-plantation administration. The afforestation industrial chain is outlined in Figure 2-4:

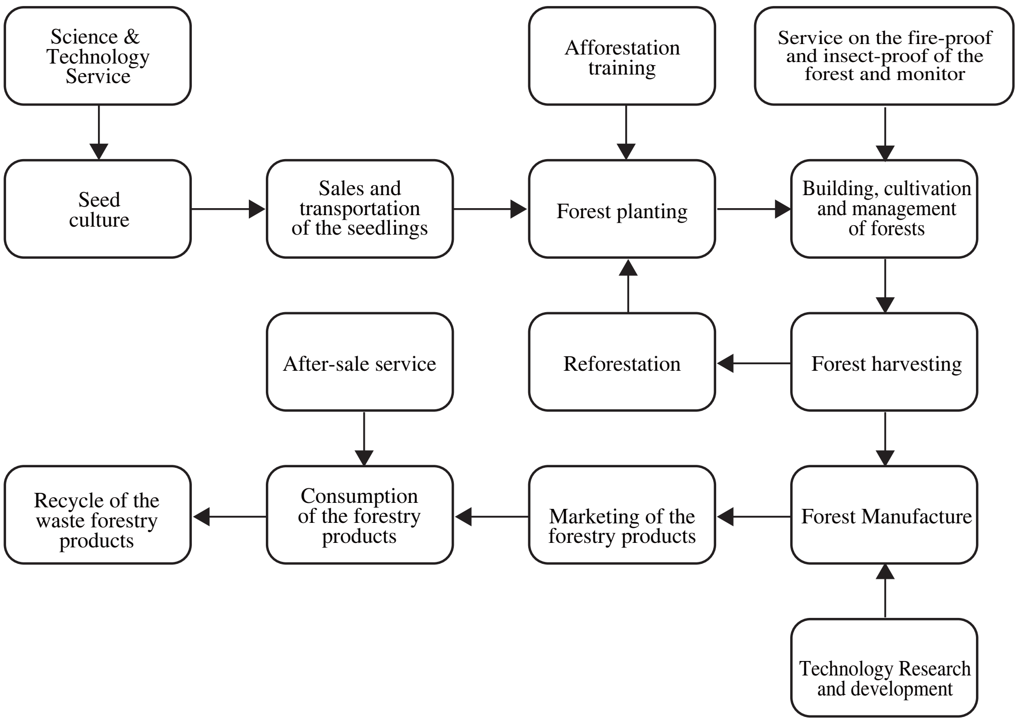

Figure 2-4: Forestation industrial chain

30 1. The afforestation area includes a retention rate up to 40% prior and 80% post-1985.
2. According to the Afforestation Technical Regulations (GB/T 15776-2006), the area of new forest conservation on non-stocked and open forest land has also been included in the total afforestation area from 2006.

1.3.2 The direct employment effect of afforestation activities

In general, large-scale afforestation will to some degree affect the way other land, such as agricultural land, is used, in turn draining rural employment. For example, afforestation of 20.01 million hectares of land was completed during 1999 to 2007, of which 8.13 million hectares was the conversion of farmland to forest. As a result, farming activities were decreased by 243.79 million work days while afforestation activities provided 113.77 million work days[31]. If work days are converted into the labour force standard (based on 300 days of work per person per year), the employment effects of afforestation policies lead to a cumulative net reduction of 433,400 jobs during this time (see Table 2-2).

Year	Total area of afforestation	Afforestation barren hills and wasteland	Converstion of farmland to forest	Increase in the labour force due to the conversion of farmland	Reduction in the labour force due to the conversion of farmland	Net reduction in the labour force	Direct reduction in jobs
	10,000 hm²	10,000 hm²	10,000 hm²	Days (1,000)	Days (1,000)	Days (1,000)	NO. of jobs (1,000)
1999	46.7	7.01	39.69	5,560	11,910	6,350	21.17
2000	88.47	45.67	42.8	5,990	12,840	6,850	22.83
2001	89.03	48.49	40.54	5,680	12,160	6,490	21.62
2002	442.36	238.38	203.98	28,560	61,190	32,640	108.79
2003	619.61	311.02	308.59	43,200	92,580	49,370	164.58
2004	321.75	239.26	82.49	11,550	24,750	13,200	43.00
2005	189.83	123.1	66.73	9,340	20,020	10,680	35.59
2006	97.7	75.85	21.85	3,060	6,560	3,500	11.65
2007	105.6	97.73	5.95	830	1,790	950	3.173
Total	**2,001.05**	**1186.51**	**812.62**	**113,770**	**243,790**	**130,020**	**433.40**

Table 2-2: The impact on employment of the conversion of farmland to forests
Data source: 1999-2007 Statistical Yearbook of China Forestry, State Forestry Administration

In fact, in addition to afforestation projects, the conversion of cultivated land to forest can create many new jobs, such as in the pre-survey and engineering planning and design phrases, engineering training and engineering assessments and monitoring etc. If the indirect employment effects of afforestation activities are considered, such as the creation of jobs in forest management and protection, forest tourism and other spin-off sectors, the impact of the conversion of cropland to forests on employment should be relatively positive. In addition, much of the land used for afforestation in China is barren hills and wasteland; even the convered farmland used is land which generates a lower output. As a measure to protect food production, from 2006, the number of initiatives which converted cultivated land to forest have been significantly been reduced and modified to consolidate the effects of previous conversion projects. During implementation, central and local governments and forestry departments have given strong emphasis to developing alternative industries and labour force training. In most regions there has generally been a good transfer of surplus labour generated from the conversion of cultivated land to forests, in which case the negative impact of afforestation projects on employment should not be considered significant as a whole.

Therefore, if the negative impact of afforestation and reforestation projects on agricultural employment is discounted, the impact on the labour force can be measured according to the area of afforestation. Based on afforestation area data from the *Chinese Forestry Statistical Yearbook (2000-2008)* and according to the afforestation labour standards from the *Shelterbelt Project Investment Index* issued by the State Forestry Administration in January 2009, the amount of labour input per hectare for afforestation (forest clearing + land preparation + saplings planted + tended, excluding daily management and protection) is around 71-136 days or an average of 103.5 days.

The short-term employment effects of afforestation

= labour per unit of afforestation area × annual afforestation area

The accumulated increase in short-term employment from China's afforestation activities during 2005 to 2008 is around 1.733 billion days (Table 2-3). If measurement is based on 300 working days per year, this can increase short

[31] Basis of calculation: The labour force standard for the conversion of cultivated land into forests is 14 days per hectare per year. The standard number of days for farming on cultivated land is 30 per hectare per year.

Source: Table 5.1, the ILO Forestry Report (p.70) at: http://www.ilo.org/public/english/dialogue/sector/techmeet/tmfwi01/tmfwir.pdf.

term employment for 5.7749 million people. The resulting impact of forestry activities on employment is therefore considerable.

Year	Total afforestation area (1,000 hectares)	Labour volume (1,000 working days)
2000	5,105.14	528,380
2001	4,953.04	512,640
2002	7,770.97	804,300
2003	9,118.89	943,810
2004	5,598.08	579,400
2005	3,637.68	376,500
2006	3,838.79	397,310
2007	3,907.71	404,450
2008	5,354.77	554,210
2003-2008	**31,455.92**	**3,255,680**
2005-2008	**16,738.95**	**1,732,470**

Table 2-3: Labour in afforestation from 2000-2008[32]

According to the State Forestry Administration's *The development of the Forestry sector within the Eleventh Five-Year Plan* China's goals for forestry development in the short, medium and long term are: to achieve forest coverage of over 20% by 2010, over 23% by 2020; and to have reached and stabilized at 26% or higher by 2050. To achieve these goals, and assuming that the forestry preservation rate is 100%, afforestation areas will need to increase. In the future, increased labour productivity brought about by technological advancements and improvements to forest management processes will reduce the labour required per hectare. Based on the average amount of labour required per hectare in China over the years, and assuming an average labour productivity rate of 20.14%, the coefficient of correction is 79.86%. Using the following formula for estimating the annual new jobs created by afforestation activities (Table 2-4):

New jobs = [labour in afforestation (work days) / (300 work days / person)] ×79.86%

Index	Forestry coverage rate	Forest area	Carbon reserves[33]	New afforestation areas	New afforestation labour	Accumulative added NO. of direct jobs
Unit	%	100 million hectares	Carbon (100 million tons)	Hectares (1,000)	Work days (million)	People (million)
2003	18.20	1.75	144.30	-	-	-
2003-2010	20.00	1.92	158.50	17,192.80	1,779.45	4.74
2003-2020	23.00	2.21	182.30	46,008.10	4,761.84	12.68
2003-2050	26.00	2.50	206.00	74,823.40	7,744.22	20.62
2005-2008	-	-	-	16,739.00	1,732.47	5.77
2003-2008				31,455.90	3,255.68	10.85
2009-2020	-	-	-	14,552.20	1,506.16	1.83
2021-2050	-	-	-	28,815.30	2,982.38	7.94

Table 2-4: Potential for carbon sinks and new jobs in China

As afforestation activities falls under the forestry sub-sector under agriculture in the input - output table, we can calculate indirect employment from afforestation according to the agricultural sector employment coefficients (Table 2-5).

[32] Afforestation activities would probably produce a crowding out effect on short-term employment in the agriculture sector. However, considering the size of the labour market in China, the scale of cultivated land converted into forestland will gradually reduced in the long term. Therefore, the calculations here ignore the negative influence on employment in agriculture.

[33] The following formulas estimate carbon reserves:

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

Formula 2: Volume of reserves per unit of forest area = forest reserves / 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 carbon forests (C2) = tree biomass carbon reserves + the amount of undergrowth + forest carbon sequestration carbon sequestration = 2.439 × 0.475 × forest reserves

Year	Indirect employment (million jobs)
2005-2008	8.416
2009-2020	2.669
2021-2050	11.581

Table 2-5: Indirect employment resulting from afforestation

1.4 Forest sustainable management

Apart from the temporary job opportunities created by seasonal afforestation projects, long term jobs may also be created in post-plantation administration. The newly created long term jobs (Table 2-6) can be calculated by using data on the newly increased areas of afforestation in 2010, 2020 and 2050, and by referring to the standard quota of workload in forest administration as published by the State Forestry Administration in its *Evaluation Guidelines for Investment in Shelter Belts*[34]. The Guidelines use one employee for the administration of 150 hectares of land per year.

Year	Newly afforested area (1,000 hectares)	Newly created long-term jobs (NO. of jobs)
2005-2008	16,738.95	89,270 – 111,590
2009-2020	14,552.18	77,610 – 97,010
2021-2050	28,815.30	153,680 – 192,100

Table 2-6: Newly created long-term jobs from forest sustainable management

Note: A range has been forecasted for the numbers of long-term jobs. The maximum is based on the forecasted value of existent labour productivity and the minimum is based on the forecasted value of improved labour productivity and techniques.

According to the Evaluation Guidelines for Investment in Ecosystem-Shelter Belts published by the State Forestry Administration, the standard cost of shelter management and protection is 48 RMB per hectare. As forest management and protection falls under the water conservation and the environment and public facilities management sectors in the input-output table, and based on the labour and indirect employment coefficient for the sector, the indirect employment effect on forest management and protection is calculated as per Table 2-7.

Year	Indirect employment (NO. jobs)
2005-2008	28,900 – 36,130
2009-2020	25,130 – 31,410
2021-2050	49,760 – 62,190

Table 2-7: Indirect employment effect of forest sustainable management

Note: The calculations project a range for numbers of long-term jobs.

The maximum is based on existing labour productivity and the minimums based on the improved labour productivity.

[34] Promulgated by the State Forestry Administration, published by China Forestry Press, 2009

1.5 Forest tourism

1.5.1 The forest tourism sector: Current status and potential for direct employment

As a crucial component of low carbon industry, forest tourism[35] will help modernize the traditional forestry industry. Following the increasing standard of living in China, eco-tourism is considered an increasingly important part of forest tourism. Forest tourism has become the tourism industry's most thriving sector, and one which has the greatest potential, dubbed "the new emerging industry of the 21st century".

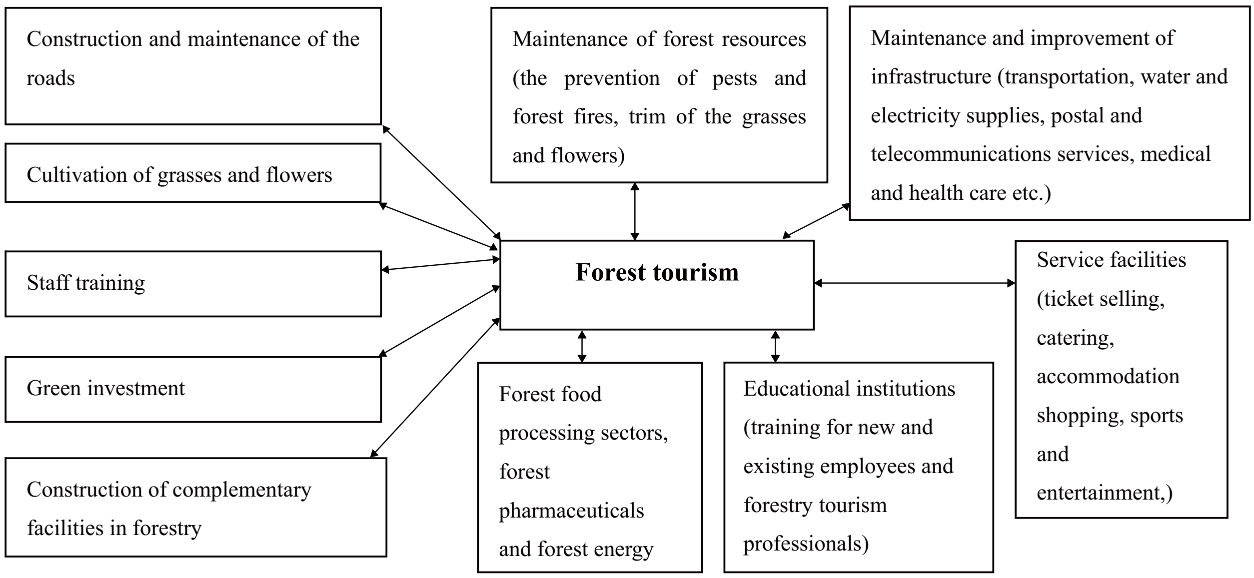

Figure 2-5: Analysis of the forest tourism industry chain

As forest tourism is a highly integrated sector with strong links to industry, it has strong spill-over effects on the national economy (Figure 2-5). Forest tourism is not only directly connected to industries such as tourism, commerce, services, transportation and forest cultivation, it has indirect links with industries such as fitness and recreation, urban construction, environmental protection, water conservation, cultural heritage, religion etc. The industry chain as a whole can create new jobs and enhance sectors in various industries, particularly in emerging sectors such as forestry health care[36], forest production, forest tourism personnel training and forest recreation and culture.

There is great potential for developing the forest tourism sector in China. There are currently over 4,200 state-owned and 150,000 joint-owned forests in China. Taking large-scale state-owned forests into account, China has rich resources on which to build forest tourism. As construction of shelter projects in China's northern and coastal areas progress and desert and mountainous regions are developed, many new forest tourist attractions are being created. Forest tourism, in the broad sense, includes activities in forest parks, wildlife conservation areas and hunting grounds. It holds potential to positively impact on the direct creation of jobs. According to national statistics, the number of employees working in forestry parks management and services across the country in 2008 reached 134,000, up from 36,000 in 1998. According to China's Forestry Yearbook, during the period of the Tenth Five-Year Plan, forest parks provide a total of over 1.6 million jobs. Since the 1990s, the State Forestry Administration created a special fund of more than RMB 1.1billion for the construction of forest parks working on a principle of "striking a balance between construction, operations and profits" and providing support to the rapid development of forest tourism (Figure 2-6).

35 Forest tourism

This study defines forest tourism as tourism-related activities that rely on the forestry environment. The modern forest tourism industry is based on the construction of forest recreation areas and tourism resources in forest parks, nature reserves, scenic spots, botanical gardens and state-owned farms etc. Due to the limited availability of data, this study only includes parks belonging to the forestry sector which account for 70-80% of the total. Therefore, the corresponding estimates of employment will be less than that expected to be generated in the forest tourism industry as a whole.

36 The "Forest health care" sector, refers to industrial clusters including fitness, recreation, recuperation and forest-derived health medicines and foods mainly coming from forest resources.

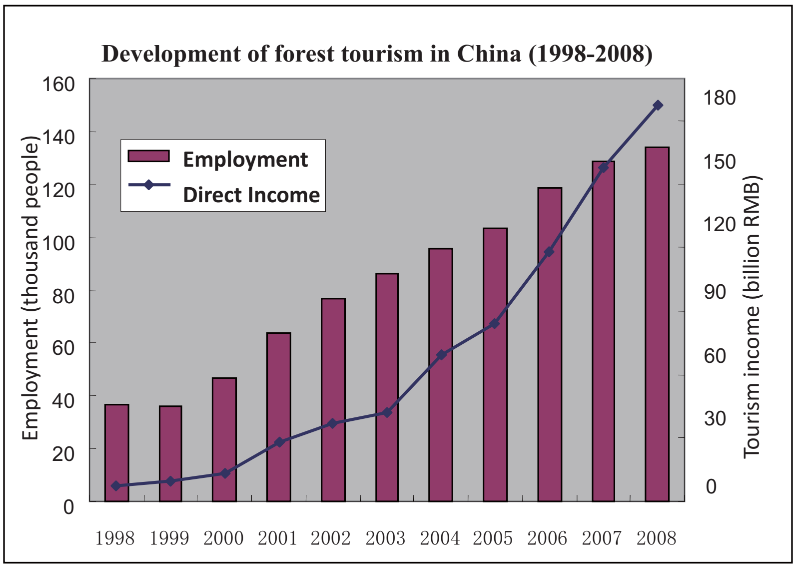

Figure 2-6: History of forest tourism
Source: China's Forestry Yearbook

While the output value of forest tourism in China has accelerated over the recent years, the scale of the industry, revenue and contribution to GDP is still small compared to other countries. Research indicates that in the USA, more than 92% of forests can be accessed by the public for outdoor recreation, with forest tourism attracting more than 300 million people and annual consumption of up to USD 300 billion. Germany has a slogan called "forests open to all". Tourist revenue from forests and parks in Germany has reached USD 8 billion, making up 67% of the total domestic tourism revenue. Latin America was one of the earliest regions to develop forest tourism and now income from forest tourism in the region accounts for over 90% of total tourism income. In contrast, the out-put value of forest tourism in China in 2008 accounted for only 12% of the total tourism income. According to estimates, by the end of 2020, forest tourism in China will reach double digit growth, and the number of Chinese tourists to forests will account for more than half the global total[37]. Based on this prediction, by 2020, the number of Chinese tourists is expected to reach 400 million[38]. The future development of the Chinese forest tourism industry presents a large amount of opportunities for green employment[39].

The future development of forest tourism in China will be influenced by many factors, such as forestry eco-construction, tourism infrastructure and social economic development. The employment elasticity of revenue can be used to show the contribution of forest tourism to employment. Taking into account the availability of data, this study used a narrow definition of forest tourism as tourism from forest parks. Based on the Forestry Department's forest park historical data, the employment elasticity of revenue for forest park tourism industry in China from 1998 to 2008 is calculated to be around 0.40. This indicates that as the revenue from forest park tourism increases by 1%, the direct employment in forest parks increases by 0.4%.

According to historical data from the *China Forestry Yearbook*, China's annual revenue from forest tourism has grown very fast, with an average annual growth rate of around 40.8%. As the growth rate of tourism revenue within this time period fluctuates greatly, there are three different development scenarios for the future of China's forest tourism industry:

(1) The high development scenario assumes the current tourism revenue growth rate will continue until 2015, after which the growth rate will decline to 20% per year.

(2) The second scenario assumes that the average annual growth rate of forest tourism will be maintained at around 20% from 2009 to 2020.

37 MiaoYaJie, The significance and countermeasures for the development of the forest tourism sector in China. [J].Journal of Modern Information, 2004(4): 202-203.

38 Yu Hui, Study on the strategy of Chinese forest tourism development in the 21st century [J]. Journal of the Forest Economy, 2001 (9): 51-53.

39 This refers to forest tourism in general, including a range of tourist activities mainly in forest parks, nature reserves, hunting grounds, etc. This study used the example of forest park tourism from the Forestry Department to forecast the potential for green job creation.

(3) The low development scenario assumes that the growth rate will be 20% from 2009 to 2015, then dropping down to 10% from 2015 onwards.

Table 2-8 shows the direct employment created by China's forest tourism industry under these three scenarios from 2005 to 2020.

Year	Development Scenario		
	High	Middle	Low
2005	103,000	103,000	103,000
2006	109,000	109,000	109,000
2007	120,000	120,000	120,000
2008	134,000	134,000	134,000
2009	155,000	146,000	146,000
2010	178,000	157,000	157,000
2011-2015	**1.362 million**	**979,000**	**979,000**
2015-2020	**2.424 million**	**1.406 million**	**1.263 million**
Total Jobs Created	**4.586 million**	**3.154 million**	**3.011 million**

Table 2-8: Forecast of direct forest tourism employment in China 2005-2020(Unit: Number jobs)
Source: statistics from China's Forestry Yearbook and the National Statistics Bureau

1.5.2 Direct employment effects on the tourism industry

It is difficult to calculate precisely the effect of tourism on job creation for two main reasons: Firstly, tourism was not listed as a separate industry in the 2005 Input-output Table issued by the National Bureau of Statistics and secondly, as tourism is connected to almost every industry in the economy, it can be difficult to distinguish tourists from local residents as their needs are very similar.

The research adopted the coefficient-free method[40] and used data from the *China Statistics Yearbook 2006*, to calculate the proportion of revenue from tourism-related industries to total output value. From this, the direct contribution rate of tourism to tertiary industry and society as a whole could be estimated along with the employment multiplier for tourism-related industries. This enabled analysis of the effect of tourism on both the social economy and employment. The approach is shown as follows:

Firstly, according to China's current statistical specifications, the tourism-related industries included in the revenue statistics fall into six categories: transportation and warehousing; postal services, retail and wholesale, catering and accommodation; residents' and other services; and culture, sports and entertainment. Revenue for each category is calculated separately in accordance with the tourism statistics. According to the literature, the breakdown of revenue from the national tourism industry is: transportation 29.8%, accommodation 17.3%, catering 18.4%, shopping 18.2%, entertainment 1.4%, sightseeing 9.5% and others 5.5%. This therefore shows the effects of tourism on revenue and direct employment in related industries. (Table 2-9)

Industries	Income contribution tourism makes to related industries %	Contribution to added value (100 million RMB)	Direct employment effects (NO. people)
Transportation and warehousing	29.8%	2,339.9	533,500
Postal services	1.4%	69.1	58,670
Retail and wholesale	18.2%	1,484.5	417,150
Catering and accommodation	17.3%+18.4%	2,421.3	392,250
Residents' and other services	5.5%	1,163.6	95,420
Culture, sports and entertainment	9.5%	2,13.42	95,610
Total	**100%**	**7,685.7**	**1,592,590**

Table 2-9: Revenue contribution and the direct employment effects of different sectors in the tourism industry in 2005

40 Li Jiangfan, LiMeiyu. On the Calculation of Tourism Industry and Tourist Added Value [J].Tourism Tribune Bimonthly, 1999 (5):16-19; Yi Shaohua. Analysis on the employment effects of the tourism industry [J].Finance and Trade Economics, 2005 (5):89-91

1.5.3 The indirect employment effects of forest tourism

Using the current statistical data, the tourism revenue from each of the related tertiary industries in 2005 was categorized, and the direct and indirect job opportunities analyzed according to the labour coefficient and employment effects. The results are shown in detail in Table 2-10.

Industries	Indirect employment (NO. people)
Transportation and warehousing	617,800
Postal service	19,600
Wholesale and retail	215,200
Accommodation and catering	610,200
Resident and other services	303,700
Culture, sport and entertainment	60,400
Total	**1,826,800**

Table 2-10 Indirect employment effects of the tourism-related industries in 2005
Source: Calculated by the author

As shown by the results, in 2005, total revenue from tourism created around 1.59 million direct job opportunities in related tertiary industries and around 1.83 million job opportunities in the expanded industry chain. According to the above-mentioned empirical data, it can be inferred that one direct job in tourism will create 1.15 job opportunities in other parts of the economy.

If the structure of the forest tourism industry is assumed to be the same as the tourism industry as a whole, the indirect employment effect can be derived as shown in the second scenario in Table 2-11.

Year	Direct Employment	Indirect Employment
2005	103,000	118,000
2006	109,000	125,000
2007	120,000	137,000
2008	134,000	153,000
2009	146,000	167,000
2010	157,000	180,000
2011-2015	979,000	1,123,000
2015-2020	1,406,000	1,613,000
Total	**3,154,000**	**3,618,000**

Table 2-11 Direct and Indirect employment effects of forest tourism (2005-2020)
Note: The total number of direct employment in forest tourism is based on data collected by Forest Parks.

1.6 Conclusions and recommendations

1.6.1 Conclusion

The forestry industry can make a significant positive contribution to mitigating climate change on a global level. The forestry industry can adapt and mitigate climate change in three main ways through carbon sinks, carbon reserves and carbon substitution. According to the results presented in this report, a range of forestry-related sectors will have a positive impact on climate change, such as afforestation, forest management and forest tourism, which can create a large number of green jobs. This has important strategic significance for the response to climate change.

The research results show that approximately 25 million green jobs can be created by afforestation activities during 2005 to 2020. Afforestation and reafforestation can directly create 7.6 million green jobs and 11 million indirect jobs. Over two million positions can be created in the sustainable forestry management sector and the total number of direct and indirect jobs created by forest tourism is 6.77 million (Table 2-12).

Employment effect		Direct Effect	Indirect Effect	Subtotal
Forestry	Afforestation & reforestation	7.6 million	11.085 million	18.685 million
	Sustainable forest management	166,900 – 208,600	54,000 – 67,500	220,900 – 276,100
	Forest tourism	3.154 million	3.616 million	6.77 million
Total		25.676 – 25.731 million		

Table 2-12: The employment effects of low carbon development in the forestry industry 2005-2020 (No people)

1.6.2 Policy recommendations

There is great potential for the development of green employment within the forestry industry. Low carbon green jobs can be created through activities in related sectors such as energy cropping, forest tourism, recreation and renewable forest products.

In order to better promote forestry industry development and green jobs creation, this study makes the following policy suggestions:

(1) **Encourage and support the development of the forestry industry and ongoing afforestation activities to create more jobs.** There is still room for development within the forestry industry. Incentives and supporting policies from government will accelerate development and create environment-friendly job opportunities. This will continue efforts to mitigate and adapt global warming and also help to alleviate employment pressures in China and the rest of the world.

(2) **Improve the coordination between government regulations of the forestry industry and markets.** Implementing a management system based on categorization and promoting innovation in investment and financing markets including the introduction of social capital are ways to enhance the management of the forestry industry. For example, to develop carbon sink forestry, public investment in afforestation activities should be accompanied by the strengthening of the forestry carbon sink market and a carbon emissions trading system to fully leverage the power of markets and the full potential of employment in this area.

(3) **Develop the forest tourism industry to promote low carbon green employment.** Forest tourism is strongly correlated with the service industries and has the ability to create direct and indirect job opportunities, including those in the tertiary sector. Therefore, the government should take appropriate measures to develop the forest tourism industry and increase investments in this sector and in related industries such as forest tourism planning and advisory services and marketing and exhibition services etc. These sectors hold great potential for the creation of green jobs.

(4) **Take measures to reduce negative impacts on employment within the industry.** The conversion of cultivated land to forests will have the effect of reducing employment in the agricultural sector. Forest conservation programs will similarly reduce the labour force in the forestry products sector. Therefore, the government, relevant departments and market organizations should ensure that measures are taking to mitigate these negative impacts on employment through training and creating opportunities for laid-off workers to transfer to or be re-employed in new roles.

(5) **Enhance the technical skills of forestry workers and increase industry awareness of decent jobs.** Compared to other professions such as manufacturing and technical services, the technical levels of employees in fields such as afforestation and forest tourism is relatively low. If the forestry industry wants to make a bigger contribution towards low carbon development, the range of current forestry projects needs to be expanded. The research findings show that the potential for low carbon development and green employment exists in many sectors but technical levels need to be increased in many fields, such as carbon–sink afforestation, forest management, forest health care product development, forest resources utilization and reuse and the forest recreation industry etc. Other initiatives to promote awareness of decent jobs and green employment in the forestry industry include public campaigns, training and education; establishing the concept of careers in forestry green jobs; improving the forestry industry’s welfare, system; establishing systems for forestry training and employment services ; and enhancing forestry workers’ awareness of decent jobs.

2. Power Industry[41]

2.1 Industry background

This section analyses the direct and indirect effects of low carbon development on employment in the power industry, in particular in the thermal power, wind power and solar power sectors.

This study uses a broad definition of the power industry which incorporates: (1) power production and supply (including management and maintenance); (2) the manufacturing of power industry equipment and related facilities; and (3) technical services such as research and development and consultation etc. The main source of data for the research came from power generation enterprises in the industry; no information was available on research and development and technical services. Due to time and human resource limitations, the analysis of the employment effects on the power industry mainly focused on enterprises in the power production and equipment manufacturing sectors.

2.1.1 The status of China's power industry

To have reliable and sustainable energy supplies is critical for a country like China which is in the process of rapid industrialization and urbanization. Coal makes up 70% of China's energy consumption, a significantly higher percentage than that of many other countries. From 2002 to 2008, electricity generation from coal was over 80% of the country's total power supply (Table 2-13). This makes reducing carbon emission levels within China's power sector a very difficult task.

Year	Hydropower			Thermal Power			Nuclear Power		
	Installed Capacity (MW)	Growth Rate (%)	Percentage of the total (%)	Installed Capacity (MW)	Growth Rate (%)	Percentage of the total (%)	Installed Capacity (MW)	Growth Rate (%)	Percentage of the total (%))
2002	86,070	3.70	24.14	265,550	4.95	74.47	4,470	112.86	1.25
2003	94,900	10.25	24.24	289,770	9.12	74.03	6,190	38.48	1.58
2004	105,240	10.90	23.79	329,480	13.70	74.48	6,840	10.50	1.55
2005	117,390	11.54	22.70	391,380	18.78	75.67	6,850	0.15	1.35
2006	128,570	9.52	20.67	484,050	23.68	77.82	6,850	0	1.10
2007	145,260	11.49	20.36	554,420	14.59	77.73	8,850	29.23	1.24
2008	171,520	15.68	21.64	601,320	8.15	75.87	9,100	2.82	1.30

Table 2-13: Statistics on total power output, 2002 to 2008

Source: Data is based on the China Electricity Yearbook and relevant reports from the China Power industry Association

Even with the development planned for the coal, hydro-electric and nuclear power sectors up to 2020, there will still be large gaps in the power supply that need to be addressed (Figure 2-7). In this context, there lies a critical need to optimize the supply and distribution of energy, speed up the development of renewable energy sources to fill "the power gap" and promote low carbon development.

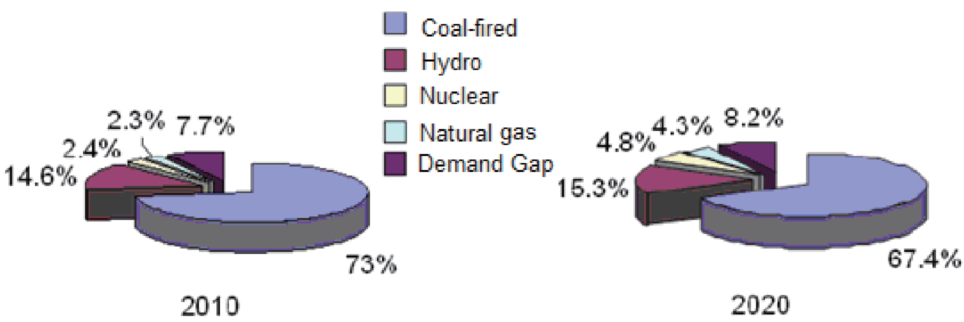

Figure 2-7: China's future power development

Source: China Electric Power Research Institute

[41] Members of the research team (Power sector): Dr. Zhang Anhua, from Energy Economics Research Center of Central University of Finance & Economics; Cao Renle, Senior Economist from the China Huaneng Group, Technology & Economy Research Institute; and Wu Jianjun, Doctoral Candidate, the North China Electric Power University, et al.

The dominance of coal in the power generation industry in China means that it has a critical role to play environmental protection, emissions reductions and China's measures to address climate change. China is the world's largest emitter of sulfur dioxide, with around 50% of emissions from thermal power, generating 12 million tons annually. China is also one of the world's largest emitters of carbon dioxide with total annual emissions from thermal power generation of around 2.8 billion tons. A reduction in emissions from the power generation industry would significantly reduce acid rain, improve environmental quality and reduce the intensity of greenhouse gases in the atmosphere.

2.1.2 Policies and measures for low carbon development in the power industry

In recent years, power industry norms, standards and management systems have been developed with a view to making resource and energy-efficiency a key factor in power industry planning, construction, production and management.

1.Policies and measures for energy saving and emissions reductions:

(1) **Develop energy-efficient technologies:** promote new energy-efficient technologies, materials and processes; invest in the research and development of such technologies as well as their application and integration into the production process, Support the continuous improvement of the power grid structure and HVDC (High Voltage Direct Current) technology, push forward the development of a large cross-regional electricity network as well as enhance efficiency in distribution.

(2) **Improve productivity by closing down small coal-fired power units:** develop high efficiency, high capacity thermal power units. By the end of 2008, high capacity 300 MW units accounted for more than 60% of total installed capacity.

(3) **Focus on energy-saving within the power grid:** in August 2007, the State Council issued the *Measures for energy-saving in the power grid dispatch (trial)*. This gave priority to the generation of electricity from wind, solar, tidal and other clean energy sources with the possibility of redistributing energy to the grid in accordance with the principles of energy-conservation, environmental protection and free markets.

(4) **Control sulfur dioxide emissions:** accelerate the construction of desulfurization facilities in coal-fired power plants. From 2006, desulphurization has greatly helped reduce levels of sulfur dioxide emissions in China. By the end of 2008, the total installed capacity of flue gas desulfurization facilities exceeded 379 GW and accounted for 66% of the total capacity of coal-fired power units in China.

(5) **Promote the domestic emissions trading scheme:** emissions trading first appeared in a formal State Council document in December 2005. In June 2007, a *Comprehensive Working Plan for Energy Saving and Emission Reduction* called for the enactment of regulations on emission trading of sulfur dioxide Emissions Trading Houses have since been established in Beijing, Shanghai, Tianjin, and Changsha.

(6) **Establish power trading rights:** Power generation trading rights aims at promoting energy saving and emissions reduction by replacing inefficient small coal-fired power units with larger highly-efficient power units. In 2007, 23 provinces took part in power generation rights trading, for an estimated 54 billion kWh of power generation.

2. Promote power generation using low carbon sources

China implemented the Renewable Energy Law in January 2006, making renewable energy a top priority in energy development. In November 2007, China promulgated the *Mid to long Term Development Plan for Renewable Energy*, thrusting power generation from renewable energy into a rapid state of development. By the end of 2008, the total installed capacity of power generation using clean and renewable energy such as hydropower, wind power and nuclear power etc. reached 190 miilion KW or approximately 24% of total installed capacity. According to China Electricity Council predictions, this proportion will increase to 26% by the end of 2010. The rapid development of power from green sources creates great potential for power industry green employment.

(1) **Hydropower:** By the end of 2008, installed capacity from hydropower reached 172GW, or 21.64% of China's total. By the end of 2008, the total installed capacity of hydropower (50MW and below) in rural areas reached 50GW with an annual power generation exceeding 150TWh. At present, there are about 50,000 small hydropower stations in operation in China. Half China's area, one third of the counties and one quarter of the population depend on electricity powered by small hydropower stations.

(2) **Wind power:** Since the introduction of the *Renewable Energy* Law in 2006, there has been rapid development

in wind power construction. By the end of June 2009, total installed capacity of wind power in China reached 16.653GW, 11.81GW of which was grid-connected. More than 240 wind farms have been built in China and there are more than 70 enterprises that manufacture wind power units in their entirety, 50 that manufacture wind turbine blades, and about 100 enterprises that manufacture wind turbine towers. By the end of 2010, the total installed capacity of wind power is expected to reach 20GW, making China one of the largest wind power markets in the world. Total installed capacity of wind power is expected to reach 100GW by the end of 2020.

(3) **Nuclear Power:** The development of nuclear power in China entered a new stage following the promulgation of the *State Plan for Medium & Long-term Development of Nuclear Power* in March 2006 and the *Medium & Long-term Nuclear Power Development Plan (2005-2020)* put forward by the State Development and Reform Commission and officially approved in November 2007. At present, 11 nuclear power units are in operation, with a total capacity of 9.1GW and 22.9GW under construction. Currently, nuclear power plants have been built at Qinshan (Zhejiang province), Da Yawan (Guangdong province), and Tianwan (Jiangsu province). It is estimated that the total installed capacity of nuclear power plants in China will reach 50 to 60GW by the end of 2020.

(4) **Solar Energy:** After years of development, the solar power industry is technologically more mature and has come of scale. By the end of 2008, the total installed capacity of photovoltaic systems reached 200MW, with more than 50 enterprises engaged in the manufacture of solar cells with a production capacity of 3500MW and an annual output of 2000MW. The beginnings of a complete industrial chain, from raw materials manufacturing to the photovoltaic system construction has been established. By the end of 2010, total installed capacity of photovoltaic power generation is expected to reach 600MW.

(5) **Biomass:** In theory, China’s biomass reserves are equivalent to around 1.5 billion tons of coal. A development target to reach 5,500MW of installed capacity for biomass was put forward in the development outline of the Eleventh Five-year Plan. Another target to reach 30,000MW by 2020 was also put forward in the *Medium & Long-term Development Plan for Renewable Energy.* By the end of 2008, total installed capacity of biomass power generation reached 3,150MW. While the technology for power generation from biomass is still in its early stages, it holds great potential for both future market development and green employment.

3.Carbon dioxide capture and storage

Carbon dioxide capture and storage technology refers to the use of technology to capture and collect carbon dioxide generated during power production, purifying emissions and reducing the emissions levels. On August 31, 2007, the China Huaneng Group and the Beijing Municipal Government signed the *Framework for Promoting Research in Carbon Capture & Processing Technology and Strengthening Energy Partnerships.* In accordance with the framework agreement, the Huaneng Group partnered with Australia’s Commonwealth Scientific and Industrial Research Organization to implement China’s first pilot capturing 3,000 tons of carbon dioxide. The project was put into operation prior to the 2008 Olympic Games in Beijing, and was completed at the Beijing Huaneng Thermal Power Plant on July 16, 2008. After several months of operation the project successfully captured thousands of tons of carbon dioxide with a purity of 99.99%. Due to the excellent social and economic results demonstrated by the pilot, the power plant intends to build a phase two project with an annual capture capacity of 60,000 tons,

2.1.3 The impact of low carbon development on employment in the power industry

There will be two impacts on power industry employment (as shown in Figure 2–8) as the industry implements low carbon development strategies to cope with climate change. Firstly, measures to conserve energy and reduce emissions will result in the closure of small inefficient and outdated thermal power plants, resulting in lay-offs. Secondly and conversely, employment opportunities will be created when activities to upscale larger thermal power plants are implemented. Low carbon green energies, such as wind, solar, hydro, biomass, geothermal and tidal power generation also have great development potential for directly and indirectly creating green employment.

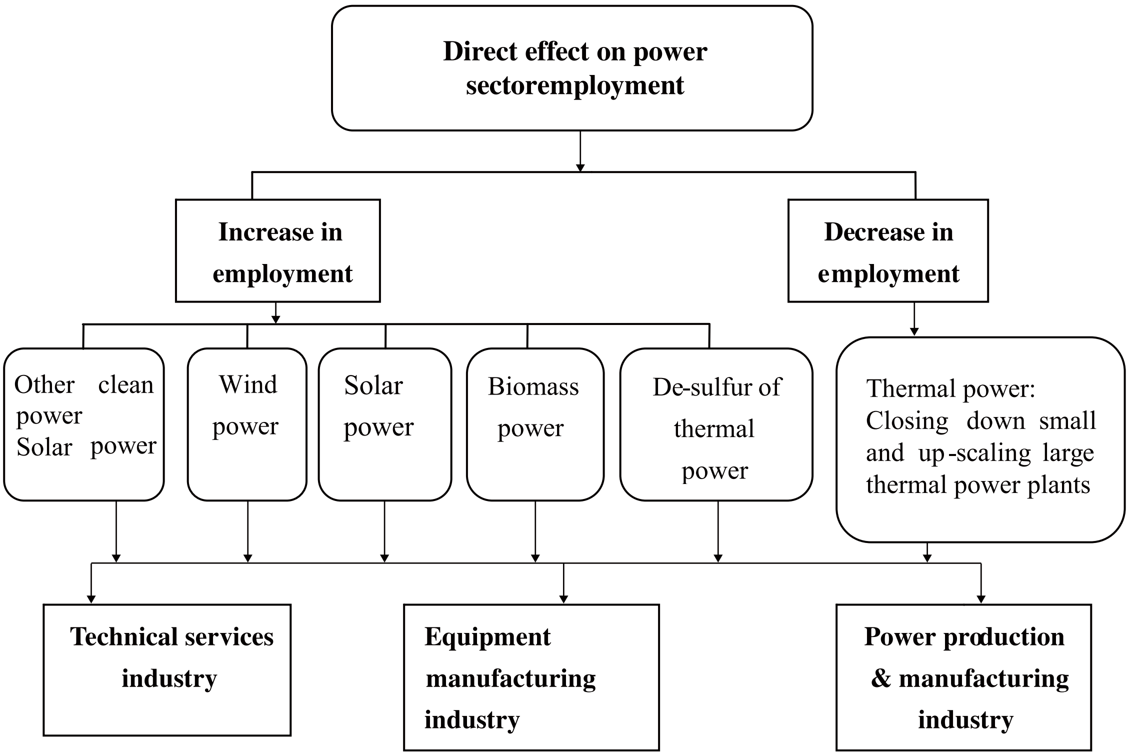

Figure 2-8 Impact of low carbon development on employment in the power industry

2.2 Coal-fired power industry

2.2.1 The employment impact of the policy to "close down small and up-scale large" thermal power plants

The policy to "shut down small and up-scale large" thermal power plants refers to replacing small scale high energy intensity thermal power plants with larger power more efficient units. According to data from the National Energy Administration, in 2008, small coal-fired power units with an installed capacity of 16,690MW, (13.9% of total installed capacity) were shut down. Over the next few years, the number of small thermal power units that are shut down will increase and be expanded to include units with 125MW or 200MW capacity that have long operating times and high coal consumption rates. By the end of 2008, total installed capacity in China reached 792GW, of which 100GW came from small power units with high energy consumption. Over the next three years, power generation units with an installed capacity of 13GW, 10GW and 8GW will be closed down, and large clean and highly energy efficient coal-fired power plants with capacities of 50GW will be constructed.

The impact of this policy on employment in the thermal power sector is quite clear: employment numbers will decrease as small thermal power units are closed but increase as new large power generation units are set up.

1. Direct and indirect impacts on employment from closing down small thermal power units

The installed capacity of small coal-fired power plants closed or to be closed in China from 2003 to 2020 is shown as follows:

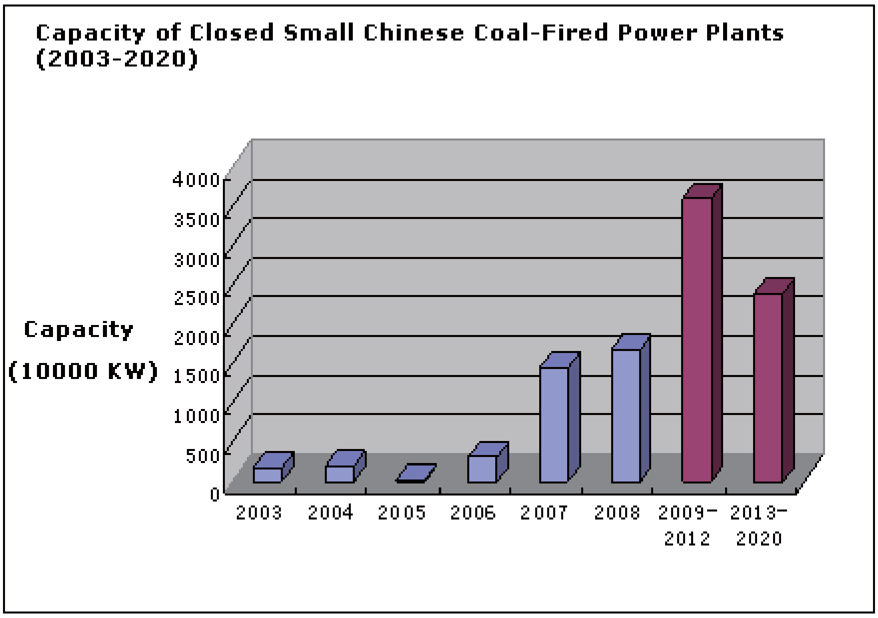

Figure 2-9: Capacity of phased-out small coal-fired power plants in China[42]

The research team obtained information on the closure of small thermal power units through literature reviews and conducting research in enterprise[43]. The results measure the impact on employment as follows: 6.2 persons will lose their jobs for every reduction or closure of 1 MW of installed capacity of small thermal power plants.

Based on above results, and assuming that the proportion of small thermal power plants closed annually is the same (the annual average being 1,293MW during 2003-2005), then the following calculations are made:

(1) From 2005 to 2008, the estimated number of jobs lost:

36,797MW × 6.2 employees / MW= 228,200 employees

(2) From 2009 to 2020, the estimated number of jobs lost:

59,800 MW × 6.2 employees / MW = 370,800 employees

Therefore, during 2005 to 2020, 599,000 jobs are estimated to be lost due to the closure of small thermal plants. If the future reduction of installed capacity is increased, e.g. plants with an installed capacity of 125MW or 200MW are closed; there will be a corresponding impact on employment through an increase in the number of jobs lost.

As the jobs to be impacted are in the production and supply electricity and heat generation, the indirect reduction in employment, as calculated using the employment coefficient of various sectors listed in Table 2, Appendix III, is shown in Table 2-14.

Year	Capacity of closed small coal-fired power plants (MW)	Direct reduction in employment (NO. persons)	Indirect reduction in employment (NO. persons)
2003-2005	3,880	24,060	27,500
2006	3,140	19,470	66,780
2007	14,380	89,160	305,810
2008	16,690	103,480	354,920
2009	13,000	80,600	212,650
2010	10,000	62,000	170,120
2011	8,000	49,600	612,430
2012-2020	28,800	178,560	2,081,670
Total	**97,890**	**606,920**	**82,520**

Table 2-14: Employees laid-off due to the closure of small coal-fired power plants (2003-2020)

[42] Source: Data published by National Development and Reform Commission and State Electricity Regulatory Commission. 2008 figures are true. Values for 2009 to 2020 are estimated.

[43] The samples include: 10 plants in Jiangxi province, 2 plants from the North China Corporation of China Power Investment Group and statistical data from closed plants in Shanxi province and the rest of China etc.

Assuming that proportion of number of small coal-fired power plants closed annually is the same (the annual average during 2003 to 2005 is 1,293MW), then we may calculate the following impact on jobs:

(1) From 2005 to 2008, the estimated number of jobs lost:

36,797MW × 6.2 employees / MW= 228,2000 employees

(2) From 2009 to 2020, the estimated number of jobs lost:

59,800 MW × 6.2 employees / MW = 370,000 employees

Therefore, the number of jobs lost due to the closure of small coal-fired plants during 2005 to 2020 will be around 599,000. If the future reduction of installed capacity is increased, e.g. plants with an installed capacity of 125MW or 200MW are closed; this will cause have a corresponding impact on employment and increase in the number of jobs lost.

2. The direct employment effects from the replacement of small coal-fired power plants

As the implementation of the policy to "close the small and up-scale the large" thermal power plants will occur at different times, not all small coal-fired power plants will be replaced by new plants with the same capacity, and some plants will be closed permanently. Assuming that the large capacity power plants built have the same capacity as those closed, employment in the new large capacity power plants can be calculated according to the new plant's average installed capacity.

(1) Thermal power production and supply

As construction of coal-fired power units with a single unit capacity of below 300MW is strictly controlled by the State, small coal-fired units are generally not lower than 300MW. Therefore, taking 300MW to be the standard capacity of large power generation units, and based on the total installed capacity and employment figures of the Huaneng Power Group, at the end of 2008, the number of employees per MW for large power generation units is calculated to be 0.603. Making the assumption that the installation of new large power generation units has been more or less completed and the replacement of small power generation units has occurred within the same period, the direct employment effect of the replacement of small power plants by large units is measured as follows:

(1) Increase in employment from newly added power generation units from 2005 to 2008:

36,797MW × 0.603 employee/MW = 22, 200 employees

(2) Increase in employment expected from the addition of new power generation units during 2009 to 2020:

59,800MW × 0.603 employee/MW = 35,600 employees

(2) Thermal power equipment manufacturing

The manufacture of coal-fired power generation units and related equipment and components are treated as part of the general and specialized equipment manufacturing sector. Based on calculations of the employment impact coefficient, the direct employment effect coefficient for the industry is 0.0142. This means that investment of RMB100 million has the potential to create jobs for 142 people. According to research in related enterprises, the average cost of manufacturing medium to large-scale power generation units and equipment in China's coal-fired power generation industry is about 3200 Yuan/KW. Based on this estimation, it is calculated that for every 1MW of newly added capacity of large power generation units, around 4.5 direct and 11.4 indirect jobs will be created in related industries within the industry chain.[44] Therefore, the output of domestic manufacturing for newly added wind power units during 2005 to 2020 have been estimated with the results shown in Table 2-15.

[44] Above calculation was based on the input-output table in 2005.

Sector	Year	Indirect Employment NO.
Coal-fired power generation and supply	2005-2008	22,200
	2009-2020	35,600
Equipment manufacturing (large coal-fired power plants)	2005-2008	165,600
	2009-2020	269,100
Total employment opportunities	2005-2020	492,500

Table 2-15: The direct employment effect created by replacing small coal-fired power plants in the coal-fired power industry from 2005 to 2020

3.The indirect employment effect created by replacing small coal-fired power units with large power generation units

Large coal-fired power units which adhere to the Chinese policy requirement for energy savings and emissions reductions can greatly improve energy efficiency and the levels of sulfur dioxide and carbon dioxide compared to the traditional small units. For this reason, the new jobs created in large power generation units can be considered to be green.

Management and maintenance personnel at large power generation units are classified as part of the electricity production and supply sectors while the manufacturing of large coal-fired power generation units falls under the general and specialized equipment manufacturing sector. Using the indirect employment impact coefficient (see Table 2 of Appendix 3) of these sectors, the results of the indirect employment effect of replacing small power units with large units are listed in Table 2–15.

Sector	Year	Indirect Employment
Coal-fired power generation and supply	2005-2008	76,140
	2009-2020	122,100
Equipment manufacture for large coal-fired power plants	2005-2008	419,840
	2009-2020	682,220
Accumulated employment opportunities	2005-2020	1,300,300

Table 2-16: The indirect employment effect created by replacing small coal-fired power plants in the coal-fired power industry during 2005-2020

4. The overall effects on employment from closing down small and up-scaling large power generation units

Overall, the direct and indirect employment effects brought about from implementing the policy to close down small power units and build up large ones can be explained as:

Employment effect (direct + indirect) =job reduction due to the closure down of small coal-fired power plants + new jobs created by the substitution of small coal-fired power plants with new large power generation units + newly jobs resulting in the related equipment manufacturing sectors.

Using the formula, the overall employment effect during 2005 to 2020 is calculated as follows:

- Direct employment effect: decrease of 599,000 persons + newly added 57,800 persons + newly added 434,700 persons = net decrease of 47,500 persons
- Indirect employment effect: decrease of 2,054,160 persons + newly added 198,240 persons + newly added 1,102,060 persons = net decrease of 753,860

Total: A net decrease of around 801,360 jobs in the coal-fired power industry during 2005-2020 due to the implementation of the policy to close down small and up-scale large thermal power plants.

While the implementation of the above-mentioned policy will have a negative impact on employment, it will bring about large environmental and social benefits. Direct reductions in coal use can occur even where small coal-fired power plant are replaced by large units of the same installed capacity, resulting in cost savings and improving output and economic efficiency. In addition, when output is unchanged, the reduction of coal consumption will decrease carbon dioxide and sulfur dioxide emissions accordingly, thus resulting in notable benefits via emissions reductions.

Reductions in emissions of sulfur dioxide from reducted coal consumption will alleviate the potential damage caused by environmental pollution. Reductions in carbon dioxide emissions will alleviate the greenhouse effect and economic benefits can be derived if emissions trading can be carried out. According to the research team's estimates, the policy to close down small power plants will bring about a reduction of coal consumption by 950 million tons, and sulfur dioxide emissions of 15.18 million tons, reducing the extent of environmental damage (such as acid rain, air pollution etc.) by about RMB 75.9 – 303.6 billion

2.2.2 The impact of sulfur dioxide emissions reductions on employment in the coal-fired power industry

Although State policy has directed a gradual decline in the proportion of coal-fired power in China's total electricity generation, coal-fired power still dominates power generation, accounting for over 70% of annual installed capacity. In order to alleviate air pollution caused by coal-fired power production, the Chinese government has promulgated a series of policies requiring power plants to install desulfurization equipment as part of power plant construction. Jobs created through by desulfurization installation are a classic example of green employment. Based on the input-output analysis framework, the macro-economic employment effect from desulfurization of the coal-fired power industry includes the creation of direct employment through the installation, maintenance and operation of desulfurization equipment and the manufacturing of desulfurization equipment, as well as the indirect effect on employment from the expansion of upstream and downstream production.[45]

1. The status of desulfurization of coal-fired power units in China

Currently, China has a total capacity of about 600 million KW of coal-fired power units, in which about 360 million KW are installed with desulfurization equipment. The installation of desulfurization equipment over time is shown in Figure 2-10.

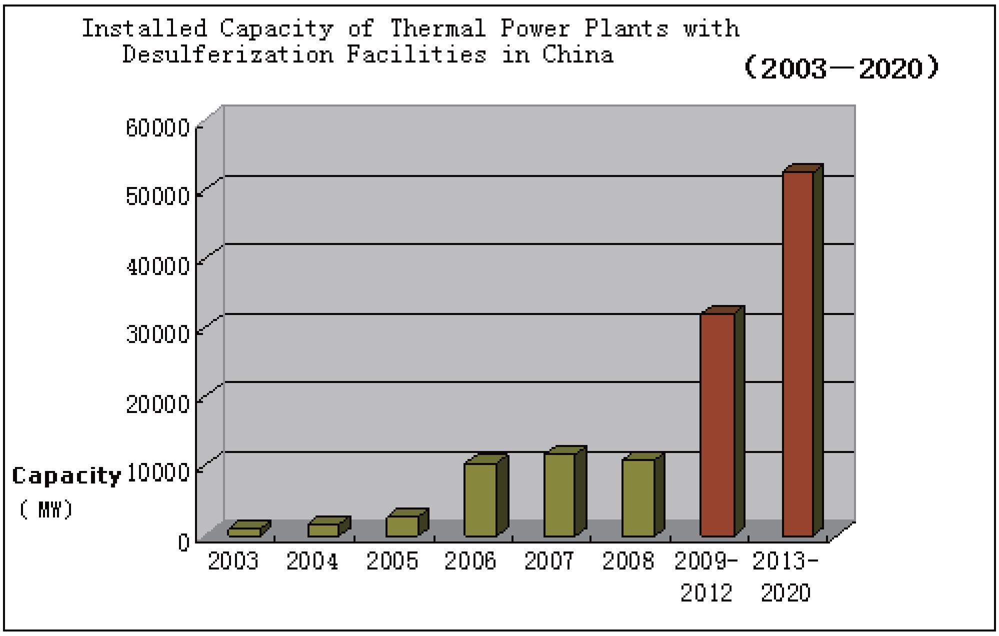

Figure 2-10: Coal-fired power plants with desulfurization facilities in China
Data source: The State Development & Reform Commission and the State Electricity Regulatory Commission. Numbers for the 2003 to 2008 period is based on real data.

45 Calculation note: (1) The material balance method was applied to calculate the reduction of sulfur dioxide and carbon dioxide emissions. For calculation purposes, 1 ton of saved coal was made equal to the reduction of 16kg of sulfur dioxide (provided that the sulfur content rate of the coal is 1 %), and 2.1267 tons of carbon dioxide; (2) The social economic benefit of the reduction of 1 ton sulfur dioxide is calculated at RMB 5000. (Research by the Chinese Research Academy of Environmental Sciences, and Tsinghua University etc. indicates that over RMB 110 billion is lost annually in China due to acid rains caused by sulfur dioxide. The annual loss due to air pollution accounted for 2-3% of total GDP in China. It is estimated that the cost of 1 ton of sulfur dioxide is about RMB 5,000 – 20,000.). The value in the reduction of 1 ton of carbon dioxide is RMB 60. (This calculation is based on the minimum price of €8 per ton as stipulated by the State Development & Reform Commission for domestic carbon trading).

2. The direct employment effects from reductions in sulfur dioxide emissions

(1) The operation and maintenance of desulfurization facilities

As the allocation of operation and maintenance personnel will increase after coal-fired power units are equipped with desulfurization facilities, the basic configuration of labour in the power sector is as follows:

- Labour for the operation of desulfurization facilities: About ten employees will be required for the operation of each control room of desulfurization equipment;

- Labour for equipment maintenance and repairs: An additional ten to 15 employees will be needed for the maintenance and repair of each set of equipment.

As the circumstances at each power plant are different, the calculation of employment across plants using the above labour allocations will vary. Therefore, the research team carried out a sample investigation, choosing 20 "typical" power plants in different regions across China. The data necessary for the sample was obtained from 18 power plants. For ease of calculations, the per person increase in employment was converted to the number of persons per unit of installed capacity. This calculated the increase in employment for each unit of installed capacity to be 0.026 person/MW[46]

According to the calculations, the installation of desulfurization equipment in coal-fired power units during 2005 to 2020 will create around 31,230 new jobs (Refer Table 2-17).

Year	Installed Capacity of Coal-fired Power Units with Desulfurization Facilities(MW)	NO. of Jobs
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
2009-2012	320,000	8,320
2013-2020	525,000	13,650
Total	**1,224,400**	**31,835**

Table 2-17: The increase number of employees from the operation and maintenance of desulfurization facilities 2003-2020

(2) The design and manufacture of desulfurization equipment

The desulfurization equipment manufacturing industry is a sub-sector of the general and specialized equipment manufacturing sector which has a labour coefficient (the impact coefficient of direct employment) of 0.0142. This means that 142 job opportunities will be created in the sector for every RMB 100 million increase in output. By calculating the per unit investment cost of desulfurization facilities, we can calculate the sector's value-added output and employment effect.

As China works towards promoting the market for and local production of flue gas desulfurization equipment, the manufacturing costs of desulfurization equipment and costs of operation will reduce greatly. When the power industry began to install desulfurization equipments in the 1990s, the cost of equipment and operation was RMB 1200/KW, but this had reached RMB 360/KW in 2005. By the end of 2005, the total installed capacity of coal-fired power units with desulfurization facilities was about 26,500MW, making the total cost of desulfurization equipment for coal-fired power generation RMB 9.5 billion. Therefore, 13,600 direct job opportunities were created for the manufacture of this equipment in one year.

Based on statistics from 2005 to 2008, and estimates of desulfurization facilities for coal-fired power units for 2009 to 2020, the direct employment effects are shown in Table 2-18.

[46] Experts agreed that the data was mainly in line with the current operational status of desulfurization power units in China.

Sector	Year	NO. of direct jobs
Operation and maintenance of desulfurization facilities	2005-2008	9,260
	2009-2020	21,970
Manufacture of desulfurization equipment	2005-2008	123,810
	2009-2020	142,980
Total employment opportunities	**2005-2020**	**298,020**

Table 2-18: The direct employment effect created by desulfurization of coal-fired power during 2005-2020

3. The indirect employment effect created by desulfurization equipment

From looking at the indirect employment impact coefficient for desulfurization equipment manufacturing (see Table-2, Appendix III), the indirect effect on employment on related sectors can be seen from the increase in investment in desulfurization equipment manufacturing. The management, operation and maintenance personnel for new desulfurization facilities is categorized as the power production and supply sector.

According to the *Eleventh Five-Year Plan for SO2 Control and Prevention in Existing Coal-fired Plants*, jointly promulgated by the State Development and Reform Commission and the State Environmental Protection Administration, there are 221 plants that need to install 137GW flue gas desulfurization equipment during the Eleventh Five-year Plan period. According to the requirements of the Plan, if the investment in desulfurization projects is calculated based on a rate of RMB 200/KW, the market volume of flue gas desulfurization equipment for existing coal-fired power plants will reach RMB 27.4 billion during the five year period. Using the input-output calculation method, this will create around 38,900 direct and 988,999 indirect employment opportunities. Using the employment impact coefficient, the indirect employment opportunities created by the desulfurization sector in China by the end of 2020 is shown the following table:

Sector	Year	Indirect Employment
Operation and maintenance of coal-fired power desulfurization facilities	2005-2008	31,700
	2009-2020	75,200
Manufacture of desulfurization equipment	2005-2008	313,500
	2009-2020	362,100
Total employment opportunities	**2005-2020**	**782,500**

Table 2-19: Indirect employment effect created by the desulfurization of coal-fired power 2005-2020

In summary, green employment opportunities created by the desulfurization sector in the coal-fired power industry during 2005-2020 is: 298,000 + 782,500 = 1.0805 million.

2.2.3 Total green employment in the coal-fired power industry

The impact of energy saving and emission reductions policies on the coal-fired power will create green employment opportunities such as in the desulfurization sector, and create job losses through the closure of small coal-fired power enterprises and units. Overall, the policy to "close down small and scale-up large" thermal power units will bring negative impacts to the coal-fired power industry through a reduction of over 0.8 million direct and indirect jobs during 2005-2020. The policy to reduce sulfur dioxide emissions will increase employment opportunities in both coal-fired power plants and in the manufacturing of desulfurization equipment, and create about 1.08 million green jobs during 2005-2020.

In general, low carbon development will have an overall positive effect on employment in the coal-fired power industry during 2005-2020. Total new job opportunities are forecast to reach 280,000, dominated mainly by indirect employment due to desulphurization in the coal-fired power sector. The results are shown in following table.

Sector	Direct Employment	Indirect Employment	Sub-total
Closure of small and the scale-up of large thermal power units	- 47,500	-753,860	-801,360
Desulfurization of coal-fired power	298,020	782,500	1,080,520
Total	**279,160**		

Tale 2-20: Total green employment in the coal-fired power industry 2005-2020

The implementation of energy saving and emission reductions in the coal-fired power industry will reduce employment in the short term as coal-fired power enterprises are closed down, operations are suspended or where a number of smaller plants are merged. It may also result in unemployment through the closure of related manufacturing enterprises. In the long term, low carbon development policies promote technical progress, energy efficiency and improve the competitiveness and growth potential for traditional coal-fired power generation enterprises. In addition, energy saving and emission reduction policies can create potential market demand for emissions reduction technology and facilities i.e. for carbon capture etc, creating direct and indirect green employment.

2.3 Wind power industry

Wind provides a clean and renewable energy source. Compared with traditional energy, wind power generation does not rely on fossil fuels, is not subject to fluctuations in the price of fuel, has a stable cost structure, and does not create air pollution or carbon emission. Given these advantages, wind power generation has become a significant source of renewable energy in many countries. According to the statistics from the 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 an annual investment of over US 20 billion dollars. Wind power in China has also sustained rapid growth. The total installed capacity of wind power in China ranked fifth in the world in 2007. It is projected that by the end of 2010, this figure will exceed 20MW,, and 100MW by the end of 2020, making China one of the largest wind power markets in the world. The fast growing wind power market in China will create large green employment opportunities in associated industries.

2.3.1 The development and direction of the wind power industry in China

To promote the development of wind power and other clean energies, China introduced the *Renewable Energy Law* in 2006. In 2007, the newly established National Energy Administration made nuclear and wind power fundamental to improving the structure of energy generation in China, with plans to build six large wind farms of 10GW in designated areas such as Inner Mongolia, Gansu, Xinjiang, Hebei and Jiangsu provinces.

According to China Wind Power Report[47], it is believed that China has the largest potential market for developing wind power in the world. China attracted 15% of global wind power investment in 2007, to a total of around €3.4 billion. According to the Europe Union, the installed capacity of wind power in China is likely to reach 20GW and 80GW by the end of 2010 and 2020 respectively, becoming the country’s third largest power source after coal and hydro-power. Since the 1990s, China’s wind power industry has experienced rapid development (see Figure 2-11). Up to the end of 2007, the total installed capacity of wind power reached 0.604GW, with an annual growth rate of over 50% over the past decade. By the end of June 2009, the total installed capacity of wind power reached 16,653MW and the total grid-connected installed capacity reached 11,810MW. More than 240 wind power generation farms have been built in China.

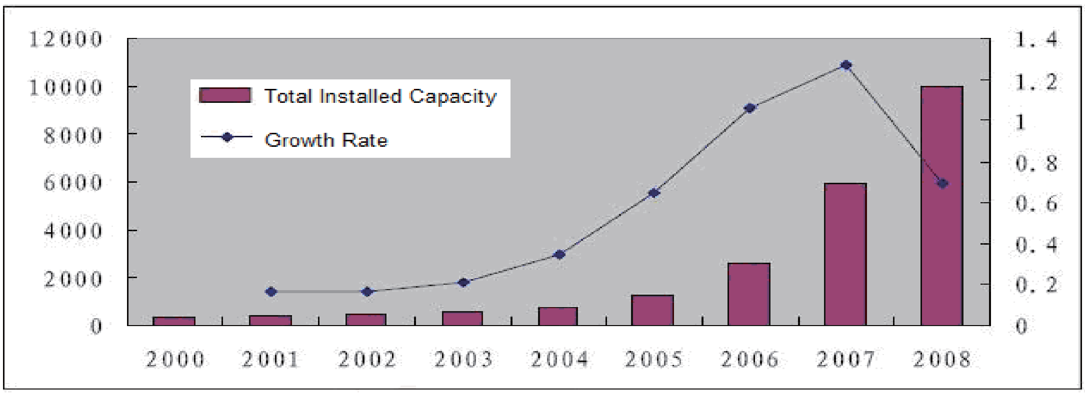

Fig. 2-11: The growth of installed capacity of wind power in China
Data source: http://www.okokok.com.cn

47 Li Junfeng et al, 2008 China Wind Power Report, Beijing, China Environmental Science Publishing House ,October 2008

The momentum of the wind power market has also promoted the rapid development of manufacturing and research and development of wind power equipment. At present, there are 185 wind power equipment manufacturers in China, including over 60 that manufacturer the wind power generator in its entirety, as well as, large numbers of manufacturers making supporting components such as wind turbine blades, wind power generators and wind turbine gearboxes. These enterprises respectively fall under the electrical equipment, aerospace and heavy machinery equipment manufacturing industries. The development of wind power will also promote the manufacturing, research and development and technical services in these sectors, creating more green employment opportunities.

2.3.2 The development of wind power internationally

According to estimates in the *2050 Energy Technology Perspective* published by the International Energy Agency, global wind power will grow by 70GW annually during 2010 to 2050, reaching a total installed capacity of 4,006GW by the end of 2050. With the rapid growth of the wind power market and many countries starting to benefit from clean power, the huge economic benefits and employment effects that could be derived from the wind power industry were being acknowledged. International institutions have since been calculating the contribution of the wind power industry towards employment.

Worldwide

The GWEC (Global Wind Energy Council) projects that global installed capacity will reach 160GW by the end of 2010, with one million people employed in industries related to wind energy. Furthermore, this figure will increase to up to three million workers by the end of 2050.

Based on development trends and the technological level of the wind power market, the report jointly published by EWEA and Greenpeace titled *Wind Force 12*, indicates that global installed capacity will reach 1260GW by the end of 2020, accounting for 12% of the world's power supply and creating 1.8 million wind power-related jobs.

European Union

According to the report titled, *Wind at Work – Wind Energy and Job Creation in the EU*, published by the European Wind Energy Association (EWEA) in early 2009, the wind energy sector in the EU employed 154,000 people in 2007. The total installed capacity of WTGS (wind turbine generator systems) of EU member states was 57.139 GW, accounting for almost 4% of the power supply in the EU.

According to EERA (European Energy Research Alliance) statistics, jobs created by the wind power industry (including manufacturing, installation and maintenance of wind power equipment) in Europe reached over 70,000 in 2002. The number of people employed in wind power industry in Germany reached 82,100 with a total installed capacity of 20.58GW.

The EWEA *Wind at Work – Wind Energy and Job Creation in the EU* report also found that the development of wind energy would provide the EU with 325,000 jobs and reach a total installed capacity of 180GW by the end of 2020.

The United States

According to a WorldWatch Institute survey, 1000GWh of electricity generated by coal or nuclear power creates 100 to 116 job opportunities while a wind farm of the same capacity can employ as many as 542.

According to research on the USA new energy policy, every one GW of wind power equipment manufactured will create 3,000 jobs in manufacturing, 700 in equipment installation, and 600 in operation and maintenance. Of these sectors, wind power equipment manufacturing accounts for 70% of total employment. In 2008, the installed capacity of wind power in the USA reached 25.17GW, overtaking Germany (23.90 GW) as number one in the world. In the USA, the number of jobs in the wind power industry hit 85,000 with 35,000 new jobs created every year.

Based on the abovementioned research on the employment effects of global wind power, the contribution of installed capacity of wind power to employment (worldwide and in some major countries) is outlined as follows:

S/N	Year	Economic Entities	Installed Capacity	Employment
1		USA	Every 1GW	4,300
2	2002	EU	23.098GW	72,275
3	2006	Germany	20.58GW	82,100
4	2007	EU	57.139GW	154,000
5	2008	Worldwide	120.791GW	400,000
6	2008	USA	25.17GW	85,000
Total			**247.778GW**	**797,675**
Number of jobs created / KW of installed capacity			3.2 people/MW	
7	2010	Worldwide	160GW	1,000,000
8	2020	Worldwide	1,260GW	1,800,000
9	2020	EU	180GW	325,000
Total			**1,600GW**	**3,125,000**
Number of jobs created / KW of installed capacity			2 people/MW	
10	2050	Worldwide	4,060GW	3,000,000
Number of jobs created / KW of installed capacity			**0.7 people/MW**	

Table 2-21: Employment opportunities created worldwide or by major economic regions in the wind power industry

As shown in the table, with technological development and the improvement of wind power operations, the number of new jobs created in the wind power industry will gradually decrease as the industry becomes saturated. The number of people employed per unit of installed capacity will decrease by about 38% by the end of 2020, and will decline by 78% by 2050 compared to 2008.

2.3.3 Wind power development on the industry chain

The wind power market includes a series of industry links in upstream product design, manufacturing, marketing, technical services, maintenance & repair, and the construction of power grid and related facilities etc. Therefore, the wind power industry in a broad sense includes technological research and development and design, equipment manufacturing (including wind turbine and components, generators etc.), technical services, and the construction of wind farms, power grids and related facilities. By separating out the segments in the industry chain, the employment effects from wind power industry development can be calculated. Direct employment opportunities created by wind power production and supply include wind farm construction, operation and electric power transmission and indirect employment opportunities are generated by the design, production, marketing and maintenance of wind power equipment, and the construction of power grid and related facilities. Induced employment is also created in these industries due to the effect on income brought about by increased employment. Due to the unavailability of data, only the direct and indirect employment effects in the wind power industry were calculated.

The following information is necessary to calculate the employment effect caused by the wind power industry:

- The investment structure of wind farms

According to the data from several typical wind farms, wind turbine generator systems (WTGS) is the core piece of equipment in wind power generation and accounts for around 60% to 80% of total wind farm investment. In addition to this are the costs of workshop construction, land use and personnel expenditure etc.

- Wind generation models and WTGS costs

Before 2005, China only manufactured WTGS with a capacity below 600KW, relying entirely on imports for key components and WTGS over 750KW.. After the introduction of the Renewable Energy Law, independent manufacturing of wind power generators in China began to take shape. This occurred by way of policy incentives, market forces as well as the accelerated transfer of wind power equipment manufacturing and design technology which brought about local production of WTGS of 750kW-1.5MW. At present, WTGS with a single set capacity 600kW -850kW accounts for about 70% of the WTGS in China. With obvious improvement in the technical performance and industrialization of mainstream WTGS, it is estimated that WTGS with about 1.5MW of single set capacity will play a dominant role in China's wind power market during the coming years. The dominant models of WTGS in the current world market have a capacity of 2MW-3MW. China is now at the stage of carrying out independent research and development and design, and it is estimated that mass production will commence gradually from 2010. Prior to 2010, 850kW WTGS was selected as the mainstream model and 1.5MW model WTGS will be the mainstream model going forward. Based on the manufacturing cost of per unit installed capacity, the employment effect caused by WTGS investment was calculated.

- WTGS manufacturing in China

Before 2007, foreign manufacturers occupied the lion's share of the wind power equipment market. In order to promote local mass production of wind power equipment, the State Development and Reform Commission required that over 70% of wind power equipment in wind farm construction should be manufactured locally. In order to get around this policy, many foreign wind power equipment manufacturers established their factories in China. By taking full advantage of the advanced technology and low labour costs in China, foreign firms were able to occupy a favorable position in the wind power equipment manufacturing industry in China. With the support of renewable energy policies available to domestic enterprises, the market share occupied by domestic WTGS manufacturers is growing steadily, from 29% in 2005 to 62% in 2008 (with around 75% occupied by new installed capacity%), and the remaining 38% funded by foreign enterprises. Currently, the top five wind power enterprises in China in terms of market share are Goldwind, Sinovel Windtec, Dongqi Wind Turbine Blade., Vestas Wind Technology and Gamesa Wind, with the top three coming from domestic manufacturers (See Table 2-22).

The local production requirement will benefit employment in the wind power industry in Chinat. While China imports a certain number of WTGS each year, WTGSs are also being exported.. For example, China exported 10,398 WTGS units in 2008 with a total value of USD 211 million in 2008.. To determine the employment effect of wind power industry development in China, (and to simplify calculations) it is assumed that 70% of total installed capacity is equipped with domestic WTGS and 30% from imported WTGS. The results of this calculation show that the wind power industry will promote domestic employment in China.

Item	Manufacturers	Capacity (kW)	Current year share of domestic & joint venture manufacturing enterprises	Current year share of new installed capacity
Domestic & joint venture manufacturing enterprises	Goldwind	2,629,050	35.02%	21.63%
	Sinovel Windtec	2,157,000	28.74%	17.75%
	Dongqi Wind Turbine Blade Co., Ltd.	1,290,000	17.19%	10.61%
	Zhejiang Windey	33,0250	4.40%	2.72%
	Nantong CASC Wanyuan Acciona Wind Turbine Manufacture Co.,Ltd	250,500	3.34%	2.06%
	Shanghai Electric	201,250	2.68%	1.66%
	Guandong Mingyang	175,500	2.34%	1.44%
	Xiangtan Electric Manufacturing Co.,Ltd	128,000	1.71%	1.05%
	Jiangsu Xinyu Wind Power	82,500	1.10%	0.68%
	Beizhong Wind Power	60,000	0.80%	0.49%
	Others	202,170	2.69%	1.66%
	Sub-total	**7,506,220**	**100.00%**	**61.76%**
Foreign funded manufacturing enterprises	Gamesa	1,552,500	33.41%	12.77%
	Vestas	1,455,200	31.32%	11.97%
	GE	637,500	13.72%	5.25%
	Suzlon	347,250	7.47%	2.86%
	Nordex	328,750	7.08%	2.71%
	Others	325,370	7.00%	2.68%
	Sub-total	4,646,570	100.00%	38.24%
Nationwide	**Total**	**12,152,790**		**100.00%**

Table 2-22: Accumulative market share of WTGS manufacturing enterprises in China in 2008
Data source: Prepared according to data from China Electricity Council and China Wind Energy Association

- Wind power research and development and maintenance services

China's is still weak in terms of research and development in the wind power industry. WTGD manufacturing enterprises have typically carried out product development by "importing new technology" and purchasing design technology and key components from foreign manufacturers, improving equipment assembling technology and technology for adjusting control systems, and gradually localizing the production of components. As China's domestic enterprises highly value the ability to improve technologically, product development has shifted from "joint design" to "independent research and development". This implies that wind power in China in the future will concentrate on the development of domestic technology and employment in the equipment manufacturing sector. As domestic manufacturing of WTGS is still in its early stages and has significant room to improve in terms of quality in comparison to foreign manufacturers, rapid development is also expected in the technological support and maintenance service industries.

- Employment in power grid construction

China's wind energy resources are mainly distributed in the "three northern (north-eastern, northern and northwestern) regions" and coastal areas, far away from major centers. These regions are precisely the weak links in the country's power grid, the concentration of large-scale wind farms in particular. By the end of 2010, ten to 20 wind power bases will be established in these regions, and another five to six extra-large wind power generation bases with a capacity of 10,000MW will be established by the end of 2020. The large-scale and long distance transmission of wind power transmission will create demand in power grid construction and extension as well as employment. This demand will mainly come from connecting wind power to the regional power grid system, including the manufacturing of transmission cable and equipment, the construction of power grid facilities and power grid maintenance etc.

2.3.4 Green employment in the wind power industry in China

This section analyzes the effect on employment in three major sectors related to the wind power industry: wind power production and supply, wind power equipment manufacturing and wind power technical services, using a bottom-up analysis method. The numbers of jobs created per unit of installed capacity is estimated using data from enterprises typical of the industry, with the indirect employment effect calculated using input-output analysis. The calculations are divided into two stages, first the calculation of the real employment effect based on past and current data acquired from research on wind power production and wind power equipment manufacturing enterprises; and the second, forecasting employment in wind power production and manufacturing based on the development of wind power market. Data for the second calculation is from an estimation of the scale of China's future wind power development.

In order to study the employment effect created by the wind power industry, the 2005 Input-output Table published by the State Statistics Bureau was used as the basis for the calculations. The table divides the economy into several sectors, and according to the input-output data, the input in equipment manufacturing and power generation processes in related sectors can be calculated along with the effect on employment in the whole economy of per unit output in the wind power industry. Wind power generation falls under the electric power, heat production and supply industry, but the WTGS manufacturing industry is not incorporated in the input-output table, instead falling under a sub-sector in the general equipment manufacturing industry. Wind power technological development and maintenance services are categorized in the scientific research and comprehensive technical services industry. (For the employment impact coefficients of the related sectors, please see Table 2, Appendix III)

1. Direct employment effect

This study defines broadly defines the wind power industry as including: (1) employment created by wind farm construction, an increase in the electricity supply, and electricity and heat production and supply in related industries; (2) WTGS equipment and component manufacturing; and (3) the technical service industries such as wind power research and development and maintenance etc.

(1) Wind power production and supply

As the input-output statistics do not separate wind power production from supply, employment for the wind power generation industry overall was calculated.

According to the data from typical wind power generation enterprises, 1.5-2.0 persons are employed for every MW of installed capacity. Based on this, employment in wind power generation enterprises in China was calculated for 2005-2010. Direct employment in the wind power generation industry during 2011-2020 was also calculated using the estimations of future employment per unit of installed capacity worldwide.. The results are as shown in Table 2-23.

Year	Installed Capacity of Wind Power(MW)	Employment NO. (persons)
2005	1,263	1,900-2,500
2006	2,599	3,900-5,200
2007	5,903	8,900-11,800
2008	12,153	18,200-24,300
2009	21,153[48]	31,700-42,300
2010	25,000[49]	37,500-50,000
2011-2020	120,000[50]	111,600-148,800[51]

Table 2-23: Employment created by wind power production and supply 2005-2020
Data source: calculated by the author.

(2) Wind power equipment manufacturing industry

WTGS and component and equipment manufacturing are classified under the general and specialized equipment manufacturing industry. According to the data from Table 2, the direct employment impact coefficient for the industry is 0.0142 i.e. investment of RMB 100 million will create142 employment opportunities. As the average price of WTGS in 2007 was around RMB 6,000-7,000/kW[52], every additional 1MW of installed capacity will create 8.5-9.9 direct jobs and 21.5-25.1 indirect jobs for sectors within the industry chain.[53] The proportion of new wind power equipment imported from overseas should also be taken into account when calculating the employment effect produced by WTGS. The total installed capacity from domestic manufacturers of new WTGS during 2005-2008 is shown in Table 2-24.

Year	New Installed Capacity(MW)	Domestic Manufacturing Share	Newl Installed Capacity Manufactured in China(MW)
2005	502	29.4%	147.6
2006	1,333	45.0%	599.9
2007	3,304	57.5%	1,899.8
2008	6,250	75.6%	4,725
2009	9,000[54]	80%[55]	7,200
2010	6,330[56]	80%	5,064

Table 2-24: New WTGS and the share of installed capacity 2005-2008
Data sources: by Shi Fengfei, past statistical data of wind farm installed capacity in China.

According to the 2008 China Wind Power Report forecasts of new wind power installed capacity, the average new WTGS installed capacity will be about 1,000MW/year by the end of 2010 based on a low development scenario with an annual growth rate of 15%. The medium development scenario forecasts about 1,330MW/year with an annual growth rate15% and the high development scenario around 6,330MW/year with an annual growth rate of 60.9%. Assuming that no large adjustments are made to China's economic structure by the end of 2010, wind power generation in 2010 is based on the input-output table's high scenario, and that local production of new installed capacity will reach 80%, the direct employment effect of new wind power equipment manufacturing is calculated at around 18,000 to 29,000 jobs.

48 According to January-June 2009 estimates.

49 Wind Power Report 2008, estimated target data for wind power development.

50 Wind Power Report 2008, estimated target data for wind power development.

51 Assuming that employment/10,000KW will drop by 38% by 2020.

52 http://www.86wind.com/info/detail/32-3554.html.

53 The calculations are based on the 2005 input-output table. The results, assume that no large adjustments were made to China's economic structure during 2006, 2007 and 2008.

54 According January-June 2009 estimates.

55 Estimated according to the new energy industry development plan promulgated by the State Development & Reform Commission. The same estimate was used in 2010.

56 Wind Power Report 2008, the estimated target data for wind power development.

(3) Technical services industry such as research and development and maintenance in the wind power industry

In countries like Denmark which has mature wind power technology and markets, jobs directly created by wind power industry are not only in wind power generation and supply and WTGS manufacturing, but also those in wind-power-related research and development and consulting. Although investment in research and development has been increasing over recent years, as China developed wind power relatively late, and most wind power technology was directly imported from overseas Although jobs in research and development and consulting are regarded as related to the wind power industry, they are not included in the wind power research and development and technical services industry for the purposes of calculation of the employment effect due to the difficulties of acquiring data.

The direct employment effect created by wind power generation and wind power equipment manufacturing during 2005-2020 is shown in Table 2-25.

Sector	Year	Direct Employment
Wind power generation	2005-2010	42,000-56,000
	2011-2020	114,000-152,000[57]
Manufacture of wind power equipment	2005-2010	163,000-196,000
	2011-2020	443,100-530,000[58]
Total	**2005-2020**	**762,000-934,000**

Table 2-25: Direct employment created by wind power industry 2005-2020 (Unit: persons)
Data sources: Calculated by the author.

2. Indirect employment effect

Induced indirect employment refers to employment in related industries such as wind power generation, manufacturing of wind power equipment and technology service etc brought about by changes in investment in the upstream and downstream industry chains which results in increase in revenue and consumption. Based on the input-output relationship, the indirect employment effect in wind power industry is as follows:

Sector	Year	Indirect Employment
Wind power generation	2005-2010	143,000-191,000
	2011-2020	390,000-520,000
Wind power equipment manufacturing	2005-2010	413,000-497,000
	2011-2010	1,122,000-1,342,000
Total	**2005-2020**	**2,068,000-2,550,000**

Table 2-26: Indirect employment created by wind power industry 2005-2020 (Unit: persons)

2.3.5 Total green employment in the wind power industry

The wind power industry holds great potential for creating green employment in China. During 2005-2020, China's wind power industry is expected to create about 2.83-3.48 million green jobs (as shown in the following table), of which, 690,000-920,000 jobs will be in wind power generation enterprises and 2.14-2.57 million in power equipment manufacturing enterprises. The wind power industry may create about 180,000-220,000 green jobs annually.

Sector	Direct Employment	Indirect Employment	Sub-total
Wind power generation	156,000-208,000	533,000-711,000	689,000-919,000
Wind power equipment manufacturing	606,000-726,000	1,535,000-1,839,000	2,141,000-2,565,000
Total	**2,830,000-3,484,000**		

Table 2-27: Total green employment in the wind power industry 2005-2020 (1,000 jobs)

2.4 Solar power industry

57 Assuming that direct employment in the wind power production and supply industry per every 10MW will decline by 20% during 2011-2020 compared to 2005-2010.

58 Assuming that the costs of manufacturing wind equipment during 2011-2020 will decline by 30% compared to 2005-2010.

Solar power generation includes power generation by solar photovoltaic and solar coal-fired energy. As solar coal-fired power generation has not been commercialized in China yet at present, there are only a few demonstration projects in operation. As a result, the research concentrates on how solar photovoltaic power generation affects employment in the solar power industry, including manufacturing of solar photovoltaic power and solar photovoltaic power generation systems.

2.4.1 The status and outlook for solar power generation in China

Solar energy is the most primitive form of energy; almost all energy sources globally are derived directly or indirectly from it. Solar energy is widely used as it can be converted into many other forms of energy. Solar energy can be used in the form of solar coal-fired energy, solar photovoltaic energy and natural solar light etc. Solar power generation includes photovoltaic power generation and solar coal-fired power generation.[59]

China is a country rich in solar energy resources, with a total reserve equivalent to 2.4 trillion tons of coal. Tibet, Qinghai, Xinjiang, Gansu, Ningxia and Inner Mongolia are the provinces which have the most abundant solar energy resources in China (See Figure 2-12).

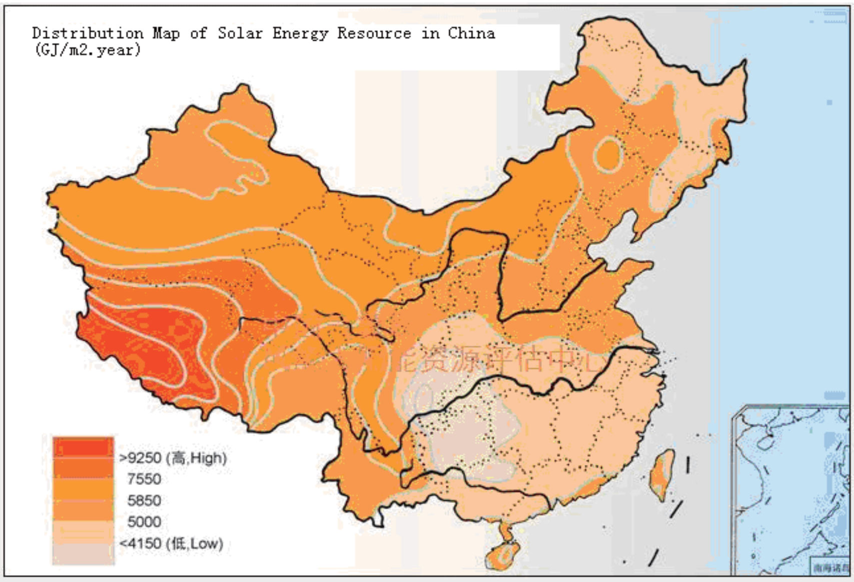

Fig. 2-12: Distribution map of solar energy resources in China[60]

With the emerging global energy crisis, solar power, as a renewable energy resource, has become the focus of many countries. Over recent years, the proportion of solar energy utilization and power generation has been rising. The development and application of solar energy has attracted much attention and has made the solar photovoltaic industry one of the most dynamic. After developing for many years, photovoltaic power generation has now become a mature and proven technology. Globally, the installed capacity of photovoltaic power generation reached 2,392MW in 2007, increasing 40% annually as shown in Figure 2-13. With improvement in energy conversion efficiency and the decreasing cost of photovoltaic cells, it is estimated that the annual growth rate of photovoltaic power generation industry will maintain over 30% till 2010, and annual sales will increase from US 7 billion dollars in 2004 to 30 billion in 2010. According to estimations by the European Photovoltaic Industry Association (EPIA), by the end of 2020, the annual global output of photovoltaic components will reach 40GW, and solar photovoltaic power generation will account for 1% of global total power generation. The rapid development of photovoltaic power generation industry will certainly promote employment both within the industry and in related sectors.

[59] The principle of solar thermal power is the use of solar thermal energy to generate electricity using a heat collector to store solar radiation which runs a generator. Solar photovoltaic power generation is achieved by the direct conversion of solar radiation into electricity without converting solar light into thermal energy.

[60] Solar and Wind Energy Resource Evaluation Center, China Meteorological Administration, “Distribution Map of Solar Energy in China”, http://cwera.cma.gov.cn/cn/

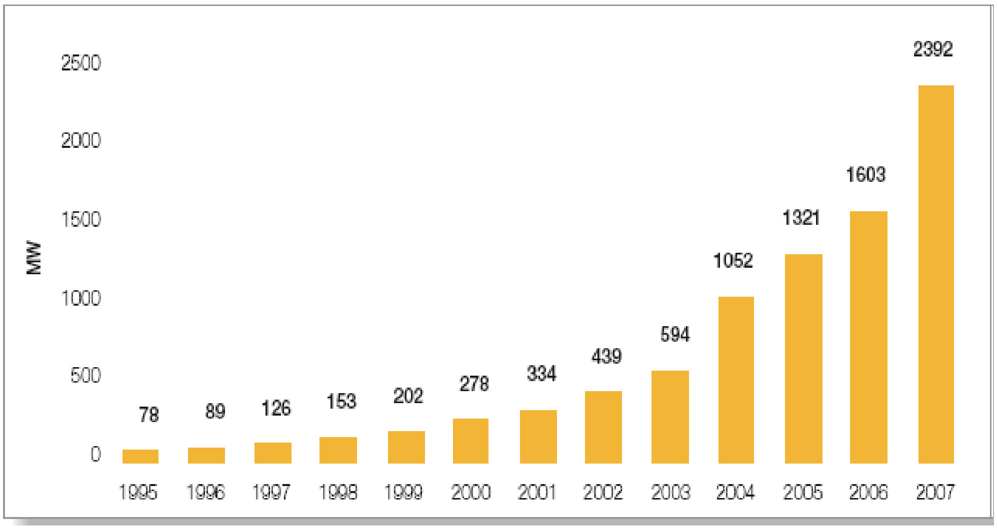

Figure 2-13: Global annual installed capacity of solar photovoltaic power generation (MW)[61]

From 2003, rapid development of photovoltaic manufacture industry in China has followed the global photovoltaic market trend. The annual output of solar cells in China reached 1,188MW, overtaking Japan and Europe, becoming the largest photovoltaic industrial base in the world. With the improvements to the domestic production capacity and technology for solar silicon materials, China has gradually established a photovoltaic manufacturing industry[62]. By the end of December 2008, more than 100 photovoltaic power generation projects were completed and connected to power grid. There were more than 500 photovoltaic enterprises in China, with over 40 enterprises specializing in materials, over 70 enterprises in silicon ingots and silicon wafers, and over 30 enterprises in cell manufacturing. Many of them have successfully stepped into international market, such as Wuxi Suntech Power, Changzhou Trina Solar Energy Co., Ltd, Baoding Tianwei Yingli New Energy Resources Co., Ltd, China Sunergy Co., Ltd., LDK Solar Co., Ltd. etc, and the photovoltaic product output of Wuxi Suntech Power and three other companies ranked among top 16 enterprises in the world. The rapid development of these enterprises has created many job opportunities.

China's photovoltaic generation industry was at its fledgling stage in the 1970s, and has experienced rapid development over recent years as shown in Figure 2-14. By the end of 2007, the total installed capacity of photovoltaic systems reached 100MW. Total power generation of solar energy reached 1.1GW, accounting for 27.5% of the world's total. From 2008, China's photovoltaic industry has maintained a high rate of growth, and total electricity output is expected to reach 2GW[63].

[61] Greenpeace, European PV Industry Association (EPIA),"Solar Generation V – 2008: Solar electricity for over one billion people and two million jobs created by 2020"

[62] "2008-2010 China Solar PV Generation Industry Analysis and Investment Consulting Report", China Investment Consulting. Website: http://www.ocn.com.cn/reports/2006103guangfufadian.htm

[63] China ranked number one in the world for solar power generation: http://cn.chinagate.com.cn/development/2008-10/30/content_16689975.htm

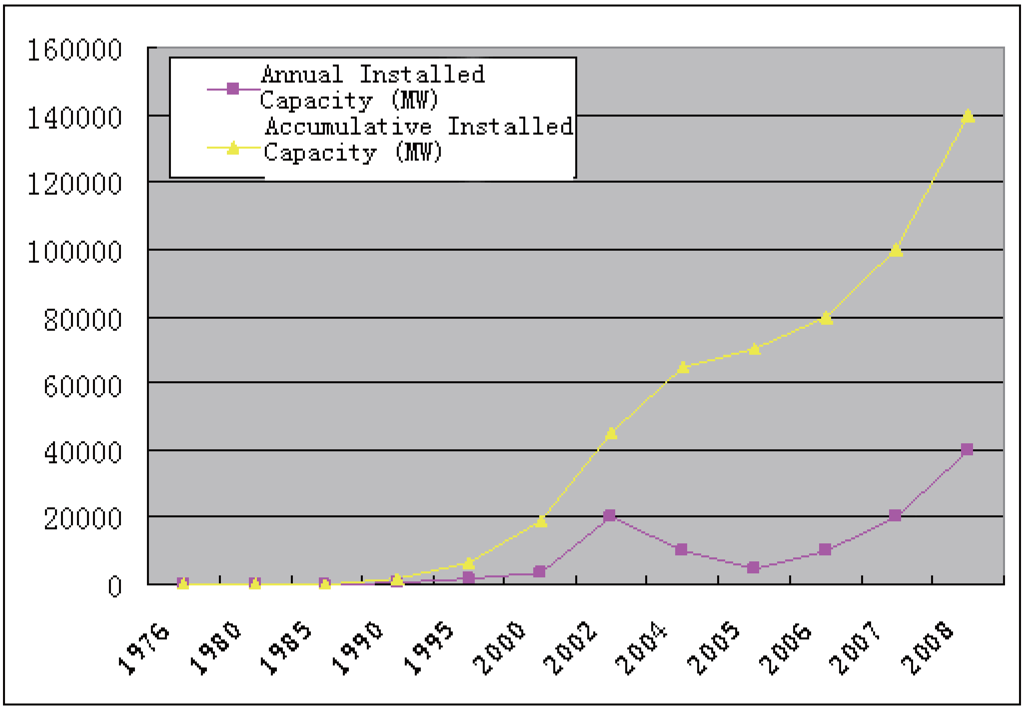

Figure 2-14: Development trend of solar photovoltaic generation in China (1976-2008)
Data sources: Prepared based on China's Photovoltaic Industry Development Repot 2007 and related data published by the Energy Research Institute National Development and Reform Commission

Due to technology and cost limitations, solar power generation in China lagged far behind the development of the photovoltaic manufacturing industry and relied heavily on technology and markets from overseas While exports of solar cells increased 1,641 times during 1990 to 2007, photovoltaic installed capacity increased only increased 39 times. During 2004 to 2006, solar cells accounted for 80%, 96.7% and 95% of total exports respectively - only a very small percentage of the solar cells manufactured were installed in China. With policies promoting low carbon development, domestic demand for solar power generation is expected to increase rapidly, thus promoting the increase of investment and employment in the solar power generation industry.

Solar power generation has a very broad application in China as shown in Figure 2-17. Using the energy efficiency of urban buildings as an example, China constructs around two billion square meters of new buildings annually, accounting for about 50% of the annual global total with buildings absorbing 20% of total energy use. In the future, buildings with photovoltaic cells are expected to become one of the most important features for many large cities in setting up a low carbon economy. Shanghai launched its *100,000 Solar Roofs Program* in 2005, the start of large-scale fit-out of solar power to buildings in China. It is estimated that by the end of 2010, China will construct around 1,000 solar panel projects with a total capacity of 50MW. By the end of 2020, the number of projects is expected to reach 20,000 with a total capacity of 1,000MW. The vast area of western China, low in population density and rich in solar energy resources is very suitable for developing household photovoltaic generation systems and small ground photovoltaic generation plants. Market demand is expected to reach 3,000MW and photovoltaic generation capacity in remote rural areas is estimated to get to 150MW by the end of 2010 and 300MW by the end of 2020. In addition, photovoltaic power generation has potential for application in many areas such as communications, meteorology, long distance pipelines, railways and highways. It's estimated that photovoltaic application in these sectors will reach 30MW by the end of 2010 and 100MW by the end of 2020. In short, the installed capacity of photovoltaic power generation in China is expected to reach 600MW by 2010 and 20GW by the end of 2020.

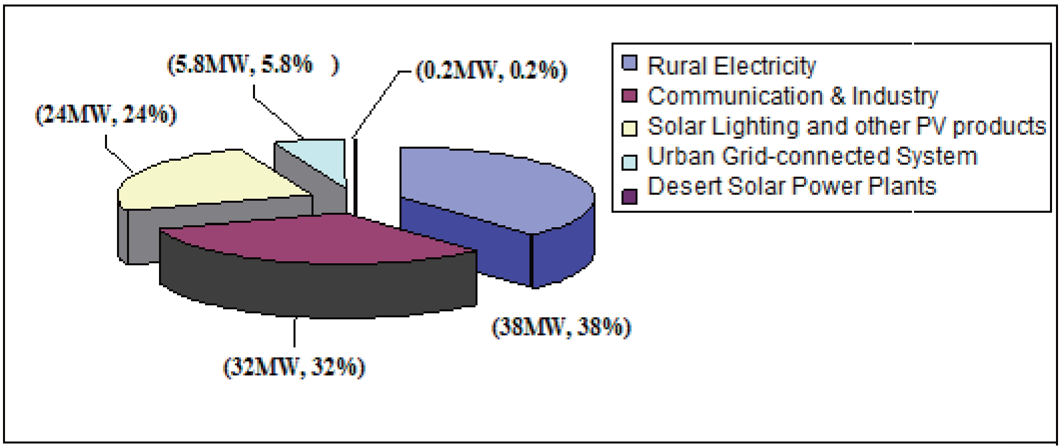

Figure 2-15: Application of solar power in China in 2007

According to the *Mid to long term Renewable Energy Development Plan*, China will go considerable efforts to enable total installed capacity of solar power generation to reach 1.8GW by the end of 2020 and 600GW by the end of 2050. It's estimated that by the end of 2050, installed capacity of renewable energy will make up over 25% of total capacity in China, with photovoltaic generation accounting for 5%. In the coming decades, the compound annual growth rate of solar power installed capacity is expected to reach over 25%.[64]

2.4.2 The direct employment effect of the solar power generation industry

The photovoltaic generation industry supply chain can be divided into five separate parts: silicon materials, silicon wafers, solar cells, solar panels, and photovoltaic power generation systems. China has established a complete industrial chain in polycrystalline silicon, silicon wafers, solar cells and solar panels, from raw materials to finished products. This research focuses on analyzing the complicated direct and indirect employment effects of photovoltaic power generation systems on the photovoltaic (PV) industry chain.

There are many sectors related to the PV industry chain. According to the 2005 Input-output Table, the employment impact coefficient of industries related to solar power generation are detailed as the following:

Solar Power Generation Industry	Statistical Sectors	Direct Employment Coefficient (Labour Coefficient)	Indirect Employment Coefficient
Solar photovoltaic power generation	Electric power and heat production and supply industry	0.0114	0.0391
Solar photovoltaic cells	Communication devices, computers and other electronic equipment manufacturing	0.0084	0.0418
	General and special equipment manufacturing	0.0142	0.036
	Electrical equipment and machine manufacturing	0.0101	0.0372
	Scientific research	0.0492	0.0342
	Technical services	0.0351	0.0354

Table 2-28: Impact coefficient of employment in major sectors

The following table shows direct employment created by the PV industry in China during 2005-2007. Data is based on analysis of the internal PV industrial chain and with reference to the China PV Industry Development Report 2004-2005 and 2006-2007.

[64] 2008-2010 China Solar PV Generation Industry Analysis and Investment Consulting Report", China Investment Consulting. Website: http://www.ocn.com.cn/reports/2006103guangfufadian.htm

Project	NO. of Jobs		
	2005	2006	2007
Polycrystalline silicon materials	1,000	3,600	7,000
Silicon ingots/ wafers	2,360	7,700	13,000
Cells	1,500	4,800	11,000
Components	2,650	9,000	25,000
System engineering and market services	2,000	2,600	3,000
Balancing components (Contra variant device and storage batteries)	500	1,000	1,500
Special materials (glass, EVA, silver/aluminum paste etc.)	500	1,800	2,500
Lighting, garden lamps, consumables manufacturing	3,000	8,500	1,500
Research and development	300	500	800
Total	**13,810**	**39,500**	**82,800**

Table 2-29: Direct employment created by photovoltaic industry 2005-2007
Data sources: China's Photovoltaic Development Report 2004-2005 and 2006-2007.

High costs have limited the development of solar photovoltaic power generation system in China. By the end of 2005, total installed capacity of photovoltaic power was only 70MW, with only 5MW added that year. The installed capacity of photovoltaic power generation systems reached 140MW by the end of 2008, with installed capacity for the year up to around 40MW. In terms of construction, photovoltaic power generation systems cost approximately 50,000 Yuan/KW in 2006, of which 66% of costs went to solar PV cells, 20% to grid-connected inverters and cables, 1.6% for equipment transportation, 3.6% for installation and debugging and 8.8% for pre-project costs, feasibility study, project design, grid-connection inspection, tax and other expenditure. The major upstream industry for photovoltaic power generation systems is solar photovoltaic cell manufacturing. The PV power generation sector is also able to develop many downstream industries such as systems engineering, market services and research and development.

About two thirds of capital used to construct photovoltaic power generation systems is in solar photovoltaic panel production which increases output and generates employment in related sub-sectors. This is in addition to output and employment generated from investments from within the solar photovoltaic cell production sector itself, even though the majority of photovoltaic solar cells are exported to meet demand from overseas.

This section analyzes the direct employment effect caused by the construction of solar photovoltaic power generation in China. The direct employment effect based on the production target for photovoltaic power generation systems during 2005-2020 is outlined in Table 2-31.

Year	2005	2006	2007	2008	2009	2010	2020
Annual installed capacity	5	10	20	40	60	90	-
Cumulative installed capacity	70	80	100	140	200	290	1600

Table 2-30: Target for photovoltaic power generation system in China 2005-2020 (Unit: MWp)

Sector	Year	NO. of jobs
Investment in construction of solar photovoltaic power generation systems	2005-2010	12,700
	2011-2020	37,600

Table 2-31: Direct employment created by investment in solar photovoltaic power generation systems 2005-2020

2.4.3 Indirect employment effect in the solar power generation industry

The indirect employment effect created by the solar power generation industry is mainly in solar power production and manufacturing and in related industries stemming from solar photovoltaic cell manufacturing. According the indirect employment coefficient of the solar power generation industry, the corresponding number jobs can be calculated.

Sector	Year	Indirect employment
Photovoltaic industry	2005	40,500
	2006	122,000
	2007	277,300

Table 2-32: Indirect employment created by solar energy power generation 2005-2007
Data sources: Calculated by the author.

As income from solar cell manufacturing is susceptible to price fluctuations, and most solar cells are exported, it is difficult to predict the impact on employment in the solar photovoltaic cell manufacturing industry within the next ten years. However, it is possible to analyze other induced employment affects over 2005 to 2020, based on the above-mentioned construction plan for solar photovoltaic power generation systems. The results are as shown in Table 2-33.

Sector	Year	Indirect Employment
Investment in the construction of solar photovoltaic power generation system	2005	9,100
	2006	16,900
	2007	31,600
	2008	58,600
	2009	81,800
	2010	114,100
	2011-2020	925,000
Total	**2005-2020**	**1,237,100**

Table 2-33: Indirect employment resulting from investmenin solar photovoltaic power generation systems 2005-2020

2.4.4 Total green employment in the solar power generation industry

There is great potential for green employment in China's solar power generation industry. The results in Table 2-34 show that around 1.29 million green jobs will be created in the photovoltaic power generation industry during 2005-2020.[65]

Sector	Direct Employment	Indirect Employment
Solar photovoltaic power generation	50,300	1,237,100
Total	**1,287,400**	

Table 2-34: Total green employment of solar photovoltaic power generation 2005-2020

2.5 Conclusions and policy recommendations

2.5.1 Conclusions

The power industry will adopt a low carbon development strategy as a means to address climate change. This will impact green employment in the power industry in two ways. Firstly, job losses will be caused by the adoption of energy saving and emissions reductions measures which bring about the closure of outdated inefficient small coal-fired power generation units. Secondly, new employment opportunities in the coal-fired power industry will be generated by investment in projects in low carbon energy and desulfurization.

Electric Power Industry	Sub-sector/policy impact	Direct Employment	Indirect Employment	Sub-total	Sub-total by sector
Coal-fired power industry	Closure of inefficient thermal power plants	- 47,500	-753,860	-801,360	279,160
	Coal-fired power desulfurization	298,020	782,500	1,080,520	
Wind power industry	Wind power generation	156,000-208,000	533,000-711,000	689,000-919,000	2,830,000-3,484,000
	Wind power equipment manufacturing	606,000-726,000	1,535,000-1,839,000	2,141,000-2,565,000	
Solar power generation industry	Solar photovoltaic power generation	50,300	1,237,000	1,287,400	1,287,400
Total	**4,397,000-5,051,000**				

Table 2-35: Total green employment in the power industry in China 2005-2020

65 Due to insufficient data, the direct and indirect employment effects brought about by photovoltaic power generation systems in the solar power generation industry excludes the employment effects in photovoltaic equipment production and manufacturing, raw material industries and other solar power generation industries. Therefore, the green employment effect calculated is smaller than that expected for the solar power generation industry.

The above table shows that the implementation low carbon development policies will result in 440,000 – 510,000 new green jobs during 2005 -2020. Clear indirect employment effects will be brought about by the investment from within the power industry and changes in the industry chain. In terms of sectors, due to low carbon development and energy saving and emissions reduction policies, the employment affects on various electric power sectors will vary significantly during 2005 -2020.

(1) Employment effect generated by the coal-fired power generation industry

The implementation of energy saving and emissions reductions policies in the coal-fired power industry mainly relates to replacement of high consumption, inefficient small coal-fired power generation units with highly energy efficient large units. The closure of small coal-fired power generation units will result in job lay-offs while the introduction of large power generation units will offset this to some extent. Overall the direct and indirect effect on employment will be a reduction in posts of around 800,000 jobs during 2005 -2020.

Another important emissions reduction measure is the reduction of sulfur dioxide emissions by the installation of desulfurization equipment in coal-fired power generation plants. If the desulfurization sector includes equipment design, manufacturing, installation and maintenance etc., then, the direct and indirect employment effect created by the coal-fired power desulfurization industry will be an increase in 1.08 million green jobs during 2005 -2020.

As a whole, the policies to shut down small inefficient thermal power units and introduce desulfurization projects in the coal-fired power industry will promote either direct or indirect employment in related manufacturing sectors. The overall effect on employment in the coal-fired power industry will be positive, with the net employment increase calculated to be around 280,000

(2) Employment effect in the wind power industry

This research demonstrates that there is great potential for green employment in China's wind power industry. About 2.83 to 3.48 million new jobs will be created by the wind power production and wind power equipment manufacturing industry during 2005-2020, in which, 690,000 to 920,000 employment opportunities will be in wind power generation enterprises, and 2.14 to 2.57 million in wind power equipment manufacturing. If a development plan for the wind power industry is made which encourages domestic wind power equipment manufacturing enterprises to improve research and development, production capacity and technical performance of their products, it will promote our traditional manufacturing enterprises to become green employers.

(3) Employment effects in the solar power generation industry

Around 440,000 to 650,000 direct and 4.3 to 6.2 million indirect employment opportunities will be created by the wind power industry during 2005 to 2020. Over this same time period, investment in the solar power generation industry is also expected to generate 50,300 direct and 367,700 indirect employment opportunities.

2.5.2 Policy recommendations

(1) **Develop renewable energies and increase the proportion of green employment in the power industry**. China's power industry has developed rapidly over recent years, but the proportion of coal-fired power generation has increased, making it more difficult to reach energy saving and emissions reductions targets. If the impact of the growth of installed capacity in the coal-fired power generation sector is not taken seriously, it will be more difficult to realize energy saving and emissions reductions in the sector. Therefore, it is recommended that power generation be promoted by low carbon or renewable means, the rate in which inefficient coal-fired power generation units are replaced is increased and green employment be created through investments in power generation by low carbon energy.

(2) **Focus on job relocation training to smooth out structural changes to power industry employment.** The impact of energy saving, emissions reductions and low carbon development policies in the power industry will be determined by how smoothly small coal-fired power generation and manufacturing enterprises can be shut down and laid-off workers transferred to new roles. Also to be managed is the shortage of workers in low carbon energy technology and management able to implement these measures. Small inefficient coal-fired power generation units should be shut down and technical personnel be trained so to improve the energy efficiency and productivity of medium and large power generation units. Power generation by renewable means and fostering partnerships with higher learning institutions that can train workers in skills related to low carbon power generation should also be encouraged. Recommendations in terms of thermal power generation include: carrying out technical upgrades to and improving the energy efficiency of existing power generation units; strengthening technical training for workers; improving management efficiency and operational performance of workers at power generation plants;,

using connotative means to improve the performance of power generation plants to bring about energy saving and emissions reductions; and building highly energy efficient power generation plants by improving the technical and management capacity of workers.

In regards to wind power and solar power generation enterprises, the employment market is currently unable to meet the industries' demand for workers. Therefore, many enterprises usually employ from within or carry out on the job training as workable solutions to increase employment within the sector.

(3) **Expand green employment channels by opening up international markets and tapping domestic market potential for power generation technology**. The following approaches are recommended: increased investment in capital and human resources necessary for research and development and market development of low carbon power generation technology; bridge the technological gap between China and other countries; become a pioneer in research and development; encourage enterprise to strengthen ties with research institutions via policy incentives; and be innovative in the development of technology thus creating jobs through induced employment by the low carbon power generation industry. Most power generation enterprises using low carbon energy in China were established by returned overseas Chinese. Equipped with advanced technology, some enterprises have kept pace with international standards and have acquired around 100 intellectual property rights and patents. In addition, these enterprises have acquired core production technology through introducing technologies from different sources, conducting independent research and development and purchasing equipment from international markets. Some are internationally competitive, for example, several leading enterprises, such as Wuxi Suntech Power, GCL Solar Energy, and Suzhou CSI Solar Technologies etc. have established subsidiary companies in the USA for the contracting of photovoltaic power generation projects, successfully edging into international market for photovoltaic power generation. The development of Chinese low carbon power generation enterprises abroad will further help to capture domestic and foreign market share, in turn, creating domestic employment.

(4) **Provide policy support to the low carbon power generation industry to boost industrial growth and green employment.** The Chinese low carbon power generation industry, like many industries, suffered the effects of the global financial crisis. Due to increasing industry competition, the acceleration of industrial integration and industry concentration, some enterprises experienced difficulties with market transformation and are at risk of collapse. Therefore, there is an urgent need for proper policy support and financial and tax relief. Concrete research should build a case for the development of the power generation industry by low carbon means. Proper plans should be outlined for the structure of the thermal power and low carbon power generation sectors. Furthermore, the healthily and orderly development of the power generation industry will bring about sustainable employment.

Enterprises should invest and develop energy-saving and environment-friendly electric power equipment which utilizes low carbon energy, such as wind, solar and biomass units so to promote development of upstream and downstream industries in the power generation industry and boost green employment.

3 Basic Industry

3.1 Employment effects on basic industry

Low carbon development has prominent effects on basic industry. While the number of workers in basic industry is seen to be positive in proportion to energy consumption, it is negative in proportion to output of the sector. Employment in basic industry is decreasing with the implementation of energy-saving and emissions reduction strategies and reductions in energy consumption. For every 1% decrease in energy consumption in basic industry, the number of jobs decreases by 1.2% (employment-energy elasticity). For every 1% increase in added value of industrial output, the number the employed in the sector will reduce by 0.4% (employment-output elasticity). It is commonly believed that the utilization of high-efficiency equipment will reduce both energy consumption levels and employment to some extent. This finding is consistent with the findings from literature reviews.

Based on forecasts of China's economic growth over the next two years, China's GDP and the added value of different industries is shown in the following table[66]:

Sector	Added Value (10 Billion RMB)					
	2005	2006	2007	2008	2009	2010
Total	1,832.17	2,045.56	2,283.80	2,489.34	2,688.49	290,357
Primary Industry (Farming, forestry, herding, and fishery, etc)	224.20	235.41	257.13	27,880	298.42	319.39
Secondary Industry	873.64	986.92	1,110.93	121,479	1,314.67	1,422.74
Basic Industry	772.30	871.75	982.66	1,072.90	1,160.08	1,254.34
Mining	102.81	116.62	130.03	141.97	15,350	16,598
Manufacturing	599.05	687.37	766.37	836.75	90,474	978.25
Power, gas, and water production and supply	67.70	77.36	86.25	94.17	101.83	11,010
Construction	101.33	115.17	128.26	141.89	15,458	168.40
Tertiary Industry	734.32	823.22	915.73	995.73	1,075.39	1,161.42
Transportation, storage and postal services	107.97	120.47	133.66	146.87	15,862	171.31
Wholesale, retail, lodging. and dining	176.65	195.58	218.51	238.97	258.09	278.74
Other	449.70	507.16	563.55	609.88	658.67	711.37

Table 3-1: Added Value in Major Sectors from 2005-2010

Based on historical analysis from 1985 to 2002, the energy intensity of basic industry decreased at an annual average rate of 1.91%. However, this rate may be taken as the rate of technological progress prior to the implementation of energy saving and emissions reduction (ESER) policies. The target to reduce energy intensity by 20% from 2005 to 2010 would mean another 2.49% decrease (a total 4.4% decrease per year) during 2005 to 2010 based on the BAU (basic as usual) scenario. Keeping the projection of basic industry added value constant[67], consideration only needs to be given to the change in the energy variable. Therefore, based on the 1.2% of energy elasticity of basic industry, as well as a reduction in total energy consumption from 2005 to 2010 of 12.45% (a saving of about 198.57 million tce), can be achieved during 2005 to 2020. Meeting the ESER goal would cause a reduction of 15.34 million jobs in basic industry or 3.07 million jobs annually[68].

3.2 Employment effects in the iron and steel industry

China is currently experiencing a process of rapid urbanization. Demand for iron and steel from industries such as construction, transportation, machinery manufacturing has been high, driving development in the sector. In this context, the Chinese iron and steel industry has experienced fast growth over the past ten years. However, due to high energy

[66] 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 based on ERI scenarios (Jiang Kejun, eta al, 2009).

[67] This hypothesis is based on output not decreasing due to ESER policy or other factors such as the impact of the global financial crisis.

[68] This estimate can be compared with similar research (Guo et al, 2009) which explores the impact on employment of international trade in 2008. Here China could experience a direct decrease of 7.93 million in 2008 from a decrease in export over the same period.

intensive manufacturing and high pollutants and greenhouse gas emissions, the industry is one of the key sectors targeted for emissions reductions. China's policies of energy-saving and emissions reduction are aimed at raising productivity and energy efficiency of the iron and steel industry as well as curbing overcapacity. These measures have corresponding impacts on employment.

3.2.1 The position and outlook for the iron and steel industry

As part of basic industry, China's iron and steel sector has been growing at a fast pace commensurate with the country's industrialization and urbanization. The gigantic Chinese iron and steel industry produces an output which accounts for 40% of the world's total, directly employing approximately 3.58 million. The following graph demonstrates the trend of iron and steel production and consumption in China since 1985.

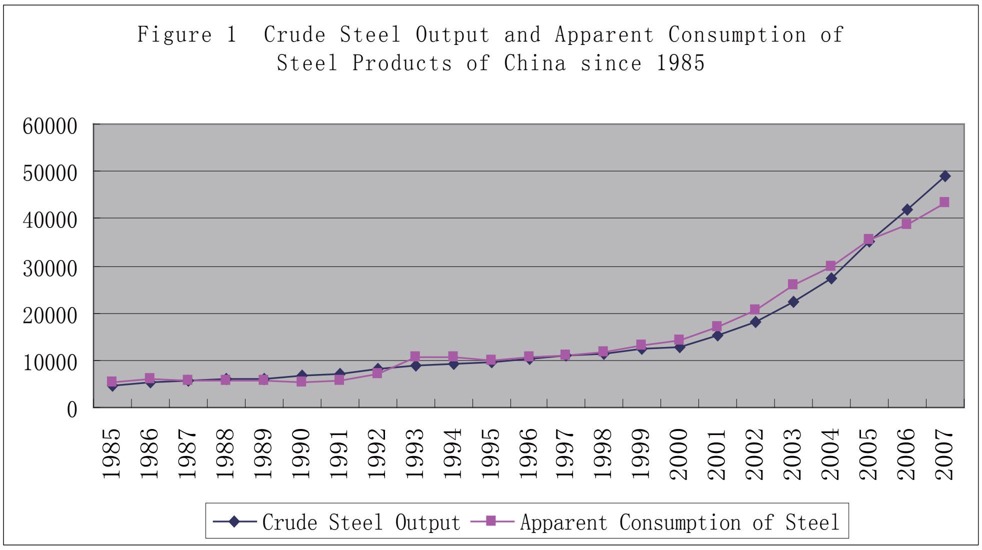

Figure 1: Crude steel output and consumption of steel products in China since 1985[69]

After years of development, China's iron and steel industry is plagued by acute overcapacity, inconsistent manufacturing technology and low industrial concentration, lagging far behind developed countries. Energy consumption levels, pollutants and industrial added value accounts for 25.1%, 10% to 16% and 8.34% of the national total but only 4.64% of employment. Therefore, the iron and steel industry is a sector typical of high carbon emissions but low employment contributions. Table 2 shows energy consumption and CO2 emissions in China's iron and steel industry over recent years, demonstrating the difficult task faced by the industry in terms of energy saving and emission reductions and climate change mitigation.

Year	Crude steel output (10,000 tons)	Energy consumption (10,000 tce)	CO2 emissions (10,000 tons)	Proportion of CO2 emissions to the national total (%)
2001	15,163.44	13,026.35	32,981.8	10.4897
2002	18,236.61	14,131.19	35,751.73	10.7635
2003	22,233.60	17,671.65	44,709.10	11.4652
2004	27,279.79	20,556.72	51,916.74	11.5859
2005	35,323.98	24,920.01	62,894.77	12.7257
2006	41,914.85	28,507.87	71,911.63	13.2354
2007	48,966.00	32,452.40	81,780.42	13.9547

Table 2: Energy consumption and carbon emissions in China's iron and steel industry

69 Source: (1) Data of crude steel output from China Steel Industry Yearbook; (2) Apparent consumption of steel products. Data of 1985-2000 come from Discussion on the development trend of China's steel products consumption, Wang Dingwu, World Metals, Oct 22 2002; Data of 2001-2007 come 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.

3.2.2 Low carbon policies in the iron and steel industry

In light of the significance of the iron and steel industry in national economy, multiple targeted policies and programs have been launched for industrial development, of which energy efficiency, emissions reductions and low carbon development are important parts. In 2005, the NDRC formulated the *Development Policies for the Iron and Steel Industry*, which directs enterprise to utilize waste gas, waste water and slag as well as work towards zero-emissions. In 2009, the State Council promulgated the *Restructuring and Revitalization Plan for the Iron and Steel Industry* that explicitly proposed the implementation of special projects for technical advancement and transformation of the steel industry and gives top priority to the recycling economy and techniques for energy efficiency and emissions reductions. The Plan defines a new energy-efficiency target for major large and medium-sized iron and steel enterprises, to which core iron and steel enterprises must meet the following by 2011: energy consumption per ton of steel of no more than 620 kg of standard coal; carbon emissions of less than 1.8 kg, and pollutant emission concentration and total pollutant emission targets.

The policy measures for energy-saving and emissions reductions in the iron and steel industry include:

(1) **Capacity replacement:** The capacity of crude steel in China hit 620 million tons in 2008, of which more than 100 million was considered excessive capacity, produced by medium and small enterprises that lacked comprehensive utilization of facilities, were inefficient and heavy polluters. Therefore energy and raw material consumption and pollutant emissions can be reduced by replacing out outdated capacity.

(2) **Using advanced technology:** Due to complex manufacturing processes and techniques adopted in iron and steel production, many energy efficiency and emissions reduction measures can be applied to the industry. In general, these measures can be divided into three categories: increasing the effectiveness of energy and raw material utilization, intensifying the recovery and utilization of secondary energy, and improving the recovery and disposal of green house gases. In particular, for all iron and steel manufacture processes, the techniques and equipment efficient in energy-saving and emissions reduction can be summarized as follows:

Processing	Techniques or Equipment
Coking	Coal moisture control equipment
	Coke dry quenching (CDQ) equipment
	Heat recovery of coke-oven gas (COG)
	The next generation coke furnace (SCOPE21)
Sintering	Boiler for heat recovery of cooler exhaust
	Boiler for heat recovery of master exhaust
Blast furnace	Top-pressure recovery turbine plant (TRT)
	BFG Combined-cycle power generation(CCPP)
	Dry-type TRT
	Pulverized coal injection (PCI)
Process Converter	Techniques or equipment
	Heat exchange for hot stoves
	Continuous casting equipment
	Sensible and latent heat recovery for Linz Donawitz Gas (LDG)
Electric furnace	DC electrical arc furnace
	Scrap preheating
Steel rolling	Double-preheating regenerative furnaces
	Hot charging and hot direct rolling
	Continuous annealing equipment
Others	Power generation with high efficiency (self-powered steel plants)
	Oxygen generating plants with high efficiency
	Recycling equipment for waste plastics

Table 3: Techniques and equipment with considerable efficiency in energy-saving and emissions reduction in the iron and steel industry

(3) **Upgrade production technology:** This refers to the replacement of high energy intensive, heavy pollutant blast furnaces with long processing times with electrical furnaces low in energy consumption, pollutants with short processing times. In fact, the differing energy consumption and pollution levels of these two processes mainly results from the use of different raw materials. Long processes use iron ore and coal while short-process use steel scrap. However, the ability to utilize short processes largely depends on raw material availability.

At present, policies which respond to climate change in China's iron and steel industry focus on capacity replacement and the application of advanced technology for energy efficiency and emissions reductions. The uptake of electrical furnace processes has been relatively slow due to limited steel scrap resources. Capacity replacement has mostly involved shutting-down outdated with strict limits on increases to advanced capacity. In 2007, the NDRC assigned the task of phasing-out of excess capacity to enterprises in the iron and steel industry, putting accountability onto local governments in 28 provinces, municipalities and autonomous regions. In 2009, the *Restructuring and Revitalization Plan for the Steel Industry* proposed a system of accountability and lifting of the existing phase-out standards. This was part of an effort to eliminate 72 millions tons of outdated capacity in iron production and 25 million tons in steel production making within 3 years.

	Capacity of blast furnaces	**Capacity of converters**	**Capacity of electrical furnaces**
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**

Table 4: Plan for phase-out of outdated capacity in China's iron and steel industry (Unit: 10,000 tons)
Source: the warrant of phase-out of lagging capacity between NDRC and governments at provincial level from NDRC website

Regarding the phase-out of outdated capacity which focuses on technical advancement and long-term development, China's core iron and steel enterprises have adopted a different strategy to that of medium and small enterprises. Only a small portion of capacity can be attributed as lagging capacity under mandatory phase-out standards while most capacity is replaced due to technical upgrades and without any explicit administrative orders. Per the *China Iron and Steel Year* Book 2008, China's major iron and steel enterprises contributed to 68.87% of total iron-making capacity and 73.45% of total steel-making capacity. Only 33 out of 948 iron and steel enterprises with outdated capacity form part of this group while the remaining 915 enterprises are mainly medium and small enterprises. Therefore, the outdated capacity of small enterprises also needs to be phased out, including 45.47 million tons of iron-making capacity and 48.39 tons of steel-making capacity. This would mean small and medium sized enterprises would confront problems as capacity shrinkage and employment relocation.

3.2.3 The impact of low carbon development on employment in the iron and steel industry

The impacts of low carbon development on employment in the iron and steel industry are mainly job losses due to the removal-out of outdated production capacity and jobs created from the adoption of energy-saving and emissions reduction technologies.

1. Job losses due to the removal of outdated production capacity

(1) Impacts on employment in iron production

As agreed upon in Letters of Commitment signed between the National Development Commission and 30 provinces, municipalities and autonomous regions, a total production capacity of 91.92 million tons is to be closed down by the end of 2010 involving 952 blast furnaces from 948 companies. Based on surveys with a number of iron and steel companies, an average of 195 jobs are lost when a blast furnace is closed down. If each province and municipality fulfills their commitment to capacity reduction, a total of 185,640 (195 × 952 =185,640) jobs will be lost.

According to the *Restructuring and Revitalization Plan for the Iron and Steel Industry,* by the end of 2011 a further 75 million tons of production capacity will be removed due to closure of blast furnaces of less than 400 cubic meters. As indicated in the letters of commitment, there are a total of 56 blast furnaces of 300 to 450 cubic meters with a production capacity of 23.41 million tons. Therefore, a capacity reduction of 75 million tons involving 180 blast furnaces will cause job losses of around 35,100.

(2) Impacts of phasing out outdated steel-making production facilities

As per the Letters of Commitment, by the end of 2010 a total production capacity of 81.27 million tons will be closed involving 122 converters and 701 electric furnaces. According to the survey findings, an average of 324 workers is employed per converter and 218 per electric furnace. Therefore, by the end of 2010 when the commitments are fulfilled, there will be a loss of 39,528 (324 ×122 = 39,528) converter jobs and 152,818 (218 × 701 = 152,818) electric furnace jobs.

According to the *Restructuring and Revitalization Plan for the Iron and Steel Industry*, by the end of 2011 another 25 million tons of production capacity will be removed from the decommissioning of converters and electric furnaces below 30 cubic tons. The closure of 44 converters will cause a loss of 14,256 jobs; the closure of 196 electric furnaces will cause a loss of 42,728 jobs. Altogether, the combined decommissioning of both converters and electric furnaces will result in 20,000 to 30,000 job losses.

The following table is a summary of the projected impact on employment due to a reduction in capacity in the iron and steel industry from 2007 to 2011:

Year	Measures	Job losses	Annual average loss
2007-2010	Capacity reduction as required by NDRC	185,600	46,,400
2007-2010	Capacity reduction as required by NDRC	152,800	38,200
2009-2011	Further reduction in capacity as required by the Restructuring and Revitalization Planning for the Iron and Steel Industry	35,100	11,700
2009-2011	Further reduction in capacity as required by the Restructuring and Revitalization Planning for the Iron and Steel Industry	20,000-30,000	6,700-10,000
Total	**393,600-403,600**		

Table 3-5: Employment effects of capacity decommissioning n the iron and steel industry

2. The impact on employment from the adoption of energy-saving and emissions reduction technology

Theoretically speaking, the adoption of energy-saving and emissions reduction technologies will help create new jobs. For example, the use of sintering gas desulphurization technology, which recycles gases formerly directly discharged into the atmosphere, requires new operational procedures, functions and jobs. The introduction of advanced technology can lead to the replacement of old jobs with new ones. For example, the use of dry coke quenching technology creates new jobs while the phasing-out of wet coke quenching will result in job losses. Generally speaking, the use of existing energy-saving and emission reduction technology will not only help reduce energy consumption, decrease greenhouse gas and pollutant emissions and recycle secondary energy, but create new jobs, easing the pressure from job losses due to technological advancements.

Due to limited sources, it was been difficult to obtain data that accurately reflects the impacts on employment of energy-saving and emission-reduction technology, Therefore, only a roughly extrapolated calculation has been provided.

(1) Impact on employment from the adoption of dry coke quenching technology

Based on data from the *Monitoring Center of China Labour Market Information Network,* by the end of 2007, there were 50,000 people employed in dry coke quenching operations. At this time dry coke quenching capacity made up one third of China's total coke production. Given the current coke production capacity, if all production plants use dry coke quenching, 150,000 workers would be employed. As traditional wet coke quenching is only one method of coke production, it is difficult to obtain an accurate estimate of the number of workers required in the sector overall. In general, dry coke quenching requires extra equipment and procedures which result in a positive impact on employment. In addition, the adoption of dry coke quenching technology will increase indirect employment associated with equipment manufacturing, installation and construction, etc.

(2) Impact of other energy-saving and emissions-reduction technologies

Only limited employment data was obtained from enterprise relating to the adoption of other energy-saving and emissions-reduction technology. Given the divergence in technology and skills among enterprises, such as sintering gas desulphurization where five different approaches are used among Chinese enterprises, each approach has different requirements and effectiveness in terms of investment, workmanship, job arrangements etc. This made interviews and data collection and thus estimating the effects on employment a difficult task.

In light of the overall potential of the above-mentioned energy saving technologies, the current scale of China's iron and steel industry and assuming that new technologies can be adopted before the 2020 energy targets, at least 200,000 direction jobs will be created.

However, in the long-term, as the iron and steel industry is not labour intensive in nature, even if the scale of production remains unchanged, continual technological progress, the replacement of outdated facilities and automation will increase productivity and result in job losses. As energy-saving and emissions-reduction technologies are continually improving, this also creates higher productivity, and the positive impacts on employment will diminish.

At present, natural resource based technologies in advanced countries are maturing, and the stock of steel materials has accumulated to an extent that provides the basic foundation for production using scrap steel. Therefore, in these countries, energy-saving and emissions-reductions focuses on replacing long production times with shorter production processes, where the increased recycling of scrap steel not only promotes energy efficiency and emissions reduction but also create many recycling-related jobs. However, in comparison, China's history of industrialization and urbanization is relatively short, its steel resources limited and the scrap recycling industry was established much later. Technology and equipment are not as advanced. As there has not been a strong scrap recycling system, a considerable portion of steel scrap required by the existing steelmaking equipment is imported, a process which is developing slowly and which is therefore not covered in this report. However, with the accumulation of steel stocks in China, the pursuance of energy efficiency and low carbon development using this approach is an inevitable trend for China.

3.2.4. Conclusions and policy recommendations

In summary, the adoption of energy saving and emissions reduction measures in China's iron and steel industry has two impacts on employment:

Firstly, the phasing-out of outdated capacity will lead to a reduction in jobs. According to the capacity reduction mission in the letters of commitment between local governments and the NDRC, and the Restructuring and Revitalization Plan for the Iron and Steel Industry, job losses of 39,000-40,000 are expected during 2007-2011.

Secondly, the adoption of energy saving technologies helps create new green jobs, with 20,000 jobs expected to be created in the iron and steel industry via the introduction of advanced technology.

In total, iron and steel industry is expected to experience a net employment decrease of 19,000 to 20,000 jobs.

1. Review policies relating to the removal of outdated production capacity and improve the re-employment policies for employees.

While the removal of outdated production capacity is an approach which contributes to low carbon development in the iron and steel industry and the rationalizing of capacity, some specific policy measures require further attention. Outdated production capacity should be given a precise definition and the exact production capacity that needs to be eliminated be determined. There should be a change in the previous methods of removed outdated capacity which only occurred on receipt of executive and administrative orders. Relying on market forces is a way to promote efficiency and naturally weed out outdated capacity. For example, increase production costs to plants with outdated capacity and provide incentives or policies which favor green development. Some outdated capacity is difficult to eliminate: not because production costs are already low, but because the costs of withdrawal are higher than the costs of production. In order to encourage enterprises to remove outdated capacity, proper withdrawal mechanisms need to be established. For example, by providing incentives or subsidies; providing employment opportunities to a proportion of workers laid off due to capacity reductions; and by reducing withdrawal costs. All these measures will contribute to the effective removal of outdated capacity.

2. Increase iron and steel industry green jobs by promoting energy-saving and emissions reduction technologies

In the long-term, low carbon development is compatible with maintaining healthy enterprise development and has significant implications for society. However, in the short term, the introduction of new technology will increase enterprise production costs, beyond the means of some small enterprises. This will have the affect of impeding the uptake of such technology. The best solution may be for the government to provide subsidies to encourage the adoption of such technologies and give equal treatment to all enterprises regardless of size. This will ensure the long-term development of the entire industry and realize the potential of the iron and steel industry for green employment.

3. Increase employment opportunities through improved technology, steel scrap use and the downstream resource recycling market

With the growing maturity of China's iron and steel industry and increasing steel inventory, steel storage will reach maximum capacity and steel scrap levels will increase. This trend should be leveraged to promote the development of the steel scrap recycling industry, and drive the steady development of electric furnace production techniques. This will have the effects of energy-saving, reducing emissions and pollutants and make positive contributions to employment.

4. Manage the transformation of the iron and steel industry and associated employee-relocation issues

Increasing the employment base is not an inherent goal of iron and steel enterprises. Normal development of the industry shouldn't be impinged by an overemphasis on employment. However, as the industry develops, it is possible consider the impacts to industry changes on employment by introducing production methods that can protect enterprise development, minimize unemployment and increase jobs. For example, at present, employment numbers can be increased by encouraging technology that supports energy-saving and emissions reductions. With the growing maturity of the industry, new jobs can be created by improving technology and techniques and increasing scrap steel recycling, and making proper arrangements for workers who face lay-offs to minimize losses. For example, workers can be placed in other roles within the same enterprise; the government can relocate laid-off workers to public service jobs;, or these workers can be given priority for training.

4 Green Investment

The 2008 global financial crisis made a large on China's terms of trade. The decline in both imports and exports caused unemployment in China's coastal regions where the economy is export-oriented. Many other domestic industries were also negatively impacted. As a counter measure, the Chinese government issued a RMB 4 trillion economic stimulus plan. This plan aimed to stimulate and sustain economic growth, adjust the structure of the economy, expand domestic demand and improve household well-being by increasing government investment. The dangers of the economic crisis were averted to some extent by the implementation of the stimulus. However, many experts believe that China is not yet in an employment–driven economic recovery phase.

Investment across different economic sectors will effect employment in different ways. As investment from the stimulus package was mainly channeled into infrastructure as a means of maintaining economic growth, the plan overlooked the positive effect this would have on employment through expansion in domestic demand and the maintenance of social stability. The *2009 Green Book of Population and Labour* designs a plan for the four trillion investment package which gives greater priority to employment creation. In this plan, 60% of investment flows into education, health, social security, residential services or related sectors. In addition to the goal to boost employment, China's economic stimulus package will also contribute to low carbon development. Up to now, there has been limited in-depth analysis and research in this area. This section will examine the economic stimulus and employment effect brought about by the 4 trillion economic stimulus plan. The research will mainly focus on the green investment component of the package which aims to promote low carbon development and environmental protection based on data issued by NDRC.

4.1 Allocation of the four trillion stimulus package and associated "green investment"

According to data published by the State Development and Reform Committee, the Chinese government made revisions to the original stimulus package (see Table 4-1).

Following these revisions, about RMB 210 billion was channeled into energy-saving and emission-reduction initiatives and an ecosystem enhancement scheme. The majority of this investment at RMB 1.5 trillion went to the infrastructure sector with 1 trillion dedicated to post-quake reconstruction in Sichuan. An additional RMB 400 billion went to the "affordable housing project" which utilizes energy-saving and environment-friendly materials. RMB 370 billion was allocated for investment in a "people's livelihood project" for the purpose of improving rural living standards in a sustainable and environment-friendly way. Investment to adjust the structure of industry and in technological innovation is estimated at RMB 370 billion while RMB 150 billion dedicated towards education, public health, cultural projects and, family planning. A significant amount of the above-mentioned investment falls into the green or environmentally-friendly category with 580 billion, or 14.5% of total investment, going to climate change-related initiatives such as those in energy-saving and emission-reduction and ecosystems..To achieve a better understanding of the positive impact of the 4 trillion stimulus package on the development of low carbon economy and job creation, this research seeks to explore the differential contribution of investment on job creation (see table 4-1).

Investment projects	Pre-adjustment (billion)	Post-adjustment (billion)	"Green investment" projects	Percentage of "Green investment"
Infrastructure (Railway, highway, airport construction, power grid)	1,800	1,500	Using more energy efficient equipment and technology to achieve energy saving targets	–
Affordable housing	280	400	Investment in energy-saving and environmental protection	–
Rural Livelihood Project construction	370	370	Rural Environmental infrastructure facilities	–

Adjustment to the industrial structure and technological innovation [70]	160	370	Optimization of the industrial structure, environmental protection technology, energy-saving projects	100%
Energy-saving and emissions-reduction and ecosystem construction	350	210	Energy-saving and emissions-reduction and ecosystem Construction	100%
Post-quake reconstruction [71]	1,000	1,000	Low carbon buildings, ,public transport, low carbon urban planning, etc.	–
Education, public health, cultural projects and public services	40	150	Popularization of science and technology	–
Total	**4,000**	**4,000**		–

Table 4-1: Components of the four trillion stimulus package and the proportion of "green investment"
Source: State Development and Reform Committee, CEIC
Note: The symbol "-" denotes that the number is still uncertain.

Based on the data in Table 4-1, in addition to the investment specifically targeting environmental protection and climate change, a large proportion of investment programs also cut across environmental protection, energy-saving and the low carbon economy (although the project team lacks specific data to support this argument). For instance, investment in infrastructure and housing could include investment in new construction materials, which may have a positive impact on the low carbon industries. The investment in the post-quake reconstruction and the rural livelihood projects may involve investment in the low carbon economy as well. Due to the lack of concrete data, the research team chose not to include these investment items in the study.

One important item in the rural livelihood project is the construction of biogas digesters in rural areas. Investment in the construction of "biogas digesters for 2.47 million households" is considered green investment. According to the National Rural Biogas Construction Investment Plan, the average investment per household is around RMB 3041. Therefore, total investment is about RMB 7.511 billion, 2% of investment in rural livelihood project construction. This investment will create around 197,000 direct rural jobs (800 jobs are created for the construction and maintenance of every 10,000 digesters). If it is assumed that 5% of the investment in livelihood project construction is green, and all of this flows into the biogas digesters project, the green investment in livelihood project construction is estimated about RMB 18.5 billion. Therefore, this research focuses on the following three issues: (1) the investment in energy-saving and emissions-reductions and ecosystem enhancement; (2) technological innovation and adjustments to the industrial structure; and (3) biogas digesters investment projects in rural areas. The total green investment of these items amounts to 598.5 billion, 15.0% of the total 4 trillion economic stimulus package.

4.2 Direction of green investment

This research analyses the input-output ratio to predict the "green investment" impact on employment. To do this, the specific proportion of "green investment" in each industry was examined closely. The analysis is as follows:

- Energy-saving and eco-construction

In the fourth quarter of 2008, the State Council approved an investment of about RMB 230 billion, of which 10% was allocated for investment in energy-saving, emissions-reductions environmental protection and eco-construction. About RMB 13 billion was used for urban construction, sewage treatment and sewerage upgrade. RMB 4 billion is designated for investment in pollution control in key areas such as the Huaihe valley, Songhuajiang river valley and the Danjiangkou reservoir area. The four billion investment was specifically aimed at improving water and waste treatment

[70] The original version is the "Investment based on independent technological innovation and industrial structural adjustment".

[71] Currently, CASS is responsible for the construction of a low carbon project in earthquake-struck Guangyuan, Sichuan Province. According to the findings of this study, the post-quake reconstruction undertaken to date had not taken the low carbon concept or low carbon technology into consideration, nor did the reconstruction relate to the construction, urban planning or new projects. Guangyuan was the first administrative unit to apply for reconstruction using low carbon technology and is now in the process of considering urban planning using low carbon technology. Guangyuan plans use the process of reconstruction to drive economic growth via low carbon means.

capabilities. Another RMB 3.5 billion was invested in the protection of natural forests and key shelterbelts.[72] China's energy-saving, emissions-reduction and eco-construction initiatives should be directed at the construction, equipment manufacturing, agriculture (forestry), hydraulic engineering, environment, and public service management industries. Using the example of a hydraulic project, it was found that the construction and installation fees and the procurement price fee accounted for 60%, 10% and 30% of investment. This can be used as a basic analysis of the differential contribution to economic growth of the impact caused by energy-saving and emission-reductions, eco-construction and environmental protection projects.[73]

- Investment in changing the industrial structure and technological innovation

Low carbon development calls for a significant amount of investment in environmental protection to go towards technological innovation and adjustments to the industrial structure. In regard to the latter, the Chinese government focus is primarily on curbing excessive industrial production and increasing output and employed in tertiary industry. In doing so, the government aims to reduce reliance on heavy industry for economic growth and improve productivity per unit of carbon consumption. Regarding technological innovation, the low carbon economy is promoted by developing new energy technologies and emissions-reducing technology such as wind power, solar power, biomass and bio-energy and carbon capture The government has also begun to promote energy efficiency and develop new energy-saving products and technologies. The present trend suggests that investment in technological innovation and adjustments to the industrial structure should be made in energy-intensive industries as well as in research and development As outlined in the *Reinvigoration Scheme for Key Industries* launched by the State Development and Reform Committee Coordination Services and the Ministry of Industry & Information, the major purpose of the four trillion investment program was to reinvigorate some traditional key industries like steel, automobiles, shipping building, petrochemicals; some light industries such as textiles, non-ferrous metals, equipment manufacturing, logistics and information technology. However, due a lack of data, a detailed analysis regarding each specific investment was unable to be carried out.

As investment in industrial structural adjustment and technological innovation can cut across a wide range of industries, the direction of the investment flow is difficult to determine. For ease of analysis and estimation, this was approached by analyzing adjustments in three major sectors of economy. Some revisions were made to the input-output table to ease with estimations for the employment impacts of structural adjustment. The employment coefficients in the three sectors of economy are per Table 4-2. There are two possibilities for investment in structural readjustment and technological innovation: economic increase based on output where about 80% of investment goes to the secondary sector and the remaining 20% to the tertiary sector; and economic increase based on job creation where about 60% of investment is injected into the secondary sector and about 40% in the tertiary sector.

Sector	Output multiplier	Impact factor	Labour coefficient	Indirect employment coefficient
The Primary Sector	2.167	0.812	0.0113	0.0211
The Secondary Sector	3.369	1.262	0.0138	0.0434
The Tertiary Sector	2.470	0.926	0.0414	0.0307

Table 4-2: The input-output impact of industry investment The above data is based on calculations by the author.

The strength of this type of analysis lies in the policy implications i.e. 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 Construction Projects

According to the National Rural Biogas Construction Plan, from 2006 to 2010 the Chinese government will help with the construction of biogas digesters for 13.18 million households. Total investment in the project is RMB 40.65 billion or RMB 8 billion per year. This is close to the estimation this study made for the biogas digester investment as part of the economic stimulus plan. According to the *Regulations for the construction of rural biogas digesters*, the capacity of each biogas digester is around 8 cubic meters. The investment in specific sectors based on the "one pool, three improvements" biogas project[74] is shown in Table 4-3 below.

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

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

[74] The basic requirement of the "one pool, three improvements" initiative are: (1) methane-generation pits of about 8 cubic meters; (2) improving the pig-pen; (3) improving the toilets; (4) improving the kitchen. See the draft version of the *Regulations for the construction of rural biogas digesters.*

Input	Expenditure Items	Percentage of Total Input %	Related I-O Sector
Construction costs	Cement, sand & stone, red brick	52.6%	Non-metal mineral products
	Steel	3.2%	Metal smelting and pressing
	Mechanics	5.3%	Comprehensive technical services
	General workers	10.5%	Construction
	Methane equipment and components	12.6%	Electronics, machinery and equipment manufacturing
Maintenance costs	Maintenance workers	15.8%	Residential and other services

Table 4-3: Construction and maintenance costs for rural biogas digesters

4.3 Analysis of "green investment"-induced employment

Based on the previous analysis, the specific allocation of "green investment" in each industry is analyzed in Table 4-4.

Project Category	Volume (Unit: 100 million)	Corresponding Industries
Energy-saving and emissions-reductions and eco-construction project	2,100	60% for the construction industry; 15% for general-purpose and specific-purpose equipment manufacturing; 15% for the electrical and industrial machinery industry; 10% for the hydraulic environmental and public service management projects
Adjustments to the industrial structure and technological innovation	3,700	70% for the secondary sector and 30% for the tertiary sector
Rural Livelihood Construction (Biogas Digesters) Project	185	52.6% for non-metal mineral products; 3.2% for metal smelting and pressing; 12.6% for electronics, machinery and equipment manufacturing; 10.5% for construction; 5.3% for the comprehensive technical services industry; 15.8% for residential and other services

Table 4-4: Allocation of "green investment"

Based on the input-output table, the output multiplier, labour coefficient, indirect- employment impact coefficient and the employment rate impact coefficient can be determined. Using this method, the effects associated with "green investment" in various industries can be determined. It is predicted that the investment in energy-saving and emission-reductions programs will generate around RMB 698.15 billion. Investment in structural adjustment and technological innovation, in the context of economic growth based on output and employment, has the potential to generate RMB 1,179.91 billion and 1,113.42 billion respectively. Investment in the Biogas Digesters Project could generate about RMB 59.03 billion Yuan. The employment impacts arising from increase in output is as follows:

4.3.1 Energy-saving, eco- construction and the impact on employment

By calculating the employment-impact coefficient, the impact on the employment rate as a result of the government's energy-saving and emissions-reductions initiatives can be determined. The results of this calculation are listed in Table 4-5. This research predicts that the energy-saving and emissions-reductions initiatives as part of China's economic stimulus plan, can generate around 567,000 jobs in some high-polluting industries and 1.51 million indirect jobs for industry in general.

Industries	Direct (No jobs)	Indirect (No jobs)
Construction	292,000	857,000
General-purpose, Special-purpose equipment manufacturing	45,000	192,000
Electrical industry and industrial machinery	32,000	18,000
Hydraulic, environment and public service management projects	198,000	288,000
Total	**567,000**	**1,517,000**

Table 4-5: The impact on employment of energy-saving and eco-construction

4.3.2 Industrial structural adjustment, technological innovation and the impact on employment

Based on hypothetical policy analysis, output-based economic growth is predicted to create around 409,000 jobs in the secondary sector, 307,000 jobs in the tertiary sector and 716,000 jobs in total. The number of indirect jobs created is expected to be around 486,000. As a result, increased job opportunities from industrial expansion could reach 2.23 million. Using an employment-led scenario, direct jobs from industrial expansion will be around 920,000 and indirect jobs around 1.42 million. The total increase in employment could reach around 2.34 million. These figures are shown in Table 4-6.

Relevant Policies	Direct Employment	Indirect Employment
Economic growth based on output (output effect: RMB 1,179.91 billion)		
Secondary Industry	409,000	396,000
Tertiary Industry	307,000	90,000
Total	**716,000**	**486,000**
Economic growth based on employment (output effect: RMB 1,113.42 billion)		
Secondary Industry	307,000	297,000
Tertiary Industry	613,000	180,000
Total	**920,000**	**477,000**

Table 4-6: The impact on employment of industrial structural adjustment and technological innovation

4.3.3 Rural Livelihood Construction Project (Biogas Digesters Project)

The employment effects, on different sectors of the economy from the implementation of the biogas digesters project is calculated based on the employment coefficient and shown in Table 4-7.

Sector	Direct Employment	Indirect Employment	Total
Construction	4,500	6,600	11,100
Non-metal Mineral Products	13,100	35,100	48,200
Electronics, Machinery and Equipment manufacturing	2,400	8,700	11,100
Metal Smelting and pressing	500	2,100	2,600
Comprehensive technical service industry	3,400	3,500	6,900
Residential service and other services	2,400	7,700	10,100
Total	**26,300**	**63,600**	**89,900**

Table 4-7: The employment effects of the rural biogas digester construction project

4.4 Conclusions

Based on the above results, green investment will create about 5.2 to 5.3 million job opportunities for China. A total of 2.08 million jobs will be created by energy-saving and eco-construction investment; 2.34 million from investment in industrial structural adjustment and technological innovation (based on the employment-led scenario data); and the Biogas Digester project can create about 90,000 jobs in rural areas.

Based on international experience, green investment should focus on fostering the role of markets and improving the technological innovation capability of enterprises. For investment in industrial structural adjustment and technological innovation, there are two scenarios: economic increase based on output and economic increase based on job creation. The total job opportunities created by these two scenarios are 2.39 million and 2.23 million respectively. Despite slightly lower output, the employment-led scenario will make a more significant contribution to employment. Therefore, investment in industrial structural adjustment should focus investment in tertiary industry technical services and research and development so to promote the long-term development of low carbon technology and improve enterprises' independent research and development and innovation capabilities. Based on this, China can achieve low carbon development and increase output in a low carbon economy.

PART III. Conclusions and Recommendations

1 Conclusions

Addressing climate change is a high level national strategy for China. China has committed to promoting low carbon development and reducing carbon emissions per unit of GDP by 40 to 45% by 2020 compared with 2005 levels. Low carbon development necessitates structural adjustments in industry and energy, directly influencing employment in different industries and regions. The aim of this study is to investigate the influence of low carbon development on employment in China and to make policy recommendations for the promotion of the dual objectives of employment creation and low carbon development.

- Macro-level analysis

The study compared the carbon productivity (carbon emissions per unit of value-add) and the carbon employment rate (the corresponding employment per unit of carbon emitted) in eight major industries. The results show that in general, low carbon development has a positive effect on employment in major industries, with primary industry having predominant advantages in terms of the carbon employment rate, and tertiary industry in terms of high carbon employment rate and carbon productivity. China's economic structure can move towards lower carbon intensity by encouraging the development of primary and tertiary industries with highly efficient carbon productivity, such as forestry and related industries. To meet energy saving and emissions reduction targets, secondary industry needs to improve in the areas of technological and management efficiency, decrease energy intensity and increase carbon productivity.

- Industry Analysis

This study analyzed the effects of low carbon development on employment in the forestry, power and steel industries and the green investment component of the economic stimulus package. The results predict that during the period 2005 to 2020, low carbon development in major industries in China will create over 30 million direct and indirect green jobs. The results are as follows:

Industry	Sub-sector	Direct Employment Effect	Indirect Employment Effect	Subtotal
Forestry (2005~2020)	Forestation and reforestation	7.6 million	11.085 million	18.685 million
	Sustainable forestry management	188,000	61,000	249,000
	Forest tourism	3.154 million	3.616 million	6.770 million
Power (2005~2020)	Thermal power	251,000	29,000	279,000
	Wind power	848,000	2.309 million	3.157 million
	Solar power	50,000	1.237 million	1.287 million
Basic industry	Steel (2007~2011)	-200,000	–	-200,000
Green investment (2008~2011)		175 million	357 million	532 million
Total	**30.759 million**			

The overall effect on employment of low carbon development in major industries in China (Unit: 1000 persons)

- Forestry

Forests provide the largest "carbon reserves" and can be a cost-effective resource for "carbon sinks". Promotion of low carbon development in the forestry industry through afforestation and reforestation, sustainable forestry management and forest tourism not only help with mitigation and adaptation to climate change, but also creates large numbers of green jobs.

Typically, afforestation is both labour-intensive and impacted by seasonal fluctuations. During 2005 to 2020, afforestation and reforestation are forecast to provide 7.6 million direct and 11 million indirect jobs. Forest management will provide more than 250,000 direct and indirect jobs, and forest tourism and related industries are expected to create 3.15 million direct and 3.62 million indirect jobs. As a whole, the forestry industry has the potential to generate 25.7 million jobs.

- Power

China's power industry plays an important role in saving energy, reducing emissions, and managing climate change. The effects of low carbon employment on the power industry are mainly expected to occur in three areas: Firstly, replacing outdated and low efficiency small generator units with large units will lead to job losses in thermal power industry. It is estimated that this will directly and indirectly reduce 800,000 jobs during 2005 to 2020. Secondly, the design, production, installation, and maintenance of desulfurization facilities associated with thermal generator units will, directly and indirectly, create 1.08 million new green jobs. Thirdly, there is great potential for development within the green energy sector, such as in wind and solar power generation, which are expected to create 4.44 million jobs from 2005 to 2020. As a whole, the power industry should focus on two areas: training that enables workers to transfer their skills, and the transformation toward low carbon energies.

- Iron & Steel

The steel industry is an energy-intensive industry, a major emitter of pollutants and greenhouse gases, and a priority sector targeted by the Chinese government for emission reductions. The employment impacts of climate change mitigation measures in the steel industry are two-fold: a reduction in jobs brought about by the removal of outdated production facilities and increases in jobs caused by the uptake of advanced energy-saving and emissions-reduction technologies.

During 2007 to 2011, it is expected that 390,000 to 400,000 jobs in the steel industry will be sacrificed due to the government's policy to remove outdated production facilities. At the same time, due to the sheer scale of the industry, it is expected that the overall promotion and adoption of advanced energy-saving and emissions-reduction technologies will create at least 200,000 direct jobs. The industry therefore faces a net reduction in jobs of around 190,000 to 200,000.

- Green Investment

In November 2008, the Chinese government launched a national stimulus package worth four trillion Yuan in which "green investment", investment closely related to climate change, accounts for 15%. The focus of green investment spending is mainly on energy-saving, emissions-reductions and eco-construction; investment in structural adjustment and technological transformation in industry; and rural methane projects. In total, green investment in the above-mentioned areas is expected to create approximately 5.3 million green jobs in China.

2 Policy Recommendations

Since the economic reforms and the opening up of China in late 1978, employment in China has continued to expand. In 2008, employment in urban areas hit 302.1 million. While the proportion of the population employed in primary industry slightly decreased, employment in secondary and tertiary industry increased with the tertiary industry seeing continuous growth In 2002, the Chinese Government began to carry out a proactive employment policy in order to ease the employment pressures resulting from laid-off workers and those entering the labour market for the first time. The policies assisted surplus rural labours find jobs in cities and towns, and adjusting and optimizing the employment structure.

Based on employment policies designed to create employment through market regulation and those that encourage workers to find their own jobs, the government has formulated and promulgated a number of relevant laws and regulations to protect the rights and interests of workers. Such laws include the *Employment Promotion Law, the Labour Contract Law, Regulations on Employment Services and Employment Management* and the *Labour Dispute Mediation Law*. The government has promoted the development of the labour market by establishing and improving employment services and social security systems and strengthening professional skills training and the management of the human resource market. This has also created a favorable environment for small and medium-sized enterprises and individuals wishing to start their own business.

From 2008, as a means to address the climate change and the global economic crisis, China has actively promoted low carbon development and stepped up its efforts to reduce energy intensity and lower greenhouse gas emissions. The result so far has been 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 actions on climate change into its economic and social development model and take the following measures: First, China will intensify efforts to conserve energy, improve energy efficiency and reduce carbon dioxide emissions per unit of GDP by 2020 from 2005 levels; second, focus will be given to the development of renewable and nuclear energy and the share of non-fossil fuels in primary energy consumption will be increased to around 15 percent by 2020; third, forest carbon sinks will be increased, 40 million hectares of forest coverage will be introduced and by 2020, 1.3 billion cubic meters of forest stock volume will increase from 2005 levels; and fourth, efforts to develop an environmentally sustainable, low carbon, circular economy will be intensified, along with research, development and the roll-out of low carbon technologies. These measures fully demonstrate China’s policy commitment of engaging in a low carbon, environmentally sustainable economy: a green economy. These policies are also expected to produce an profound effect on employment in related industries.

Energy conservation, emissions reductions and the development and protection of the environment are the major ways of promoting low carbon development in China. Although energy conservation and emissions reductions initiatives have negative impacts on employment in industries related to fossil fuels, the advancements in technology and cost reductions which they bring will contribute to long term economic development. Environmental development has positive impacts on employment in the forestry sector, including in forestation, reforestation, eco-system management and, forest eco-tourism etc.

The following recommendations are proposed to promote low carbon development and meet the low carbon employment target:

(1) Promote low carbon development and introduce policies to promote green employment

The impacts of low carbon development vary across different industrial sectors. Future policies for low carbon development in China are forecast to stimulate tens of millions of direct and indirect green jobs. The potential for low carbon employment, therefore, can be harnessed if enterprise and industry adopt low carbon development policies such as energy efficiency, emissions reductions, eco-development and optimizing the industry structure. If these policies are supported by effective employment promotion, the outcomes of the policies can be achieved while upgrading the employment structure and improving the income levels of workers. These changes would shift the mode of development of the Chinese economy from investment-driven to consumption-driven, and improve the economic structure and employment in the long term. For example, in order to encourage green job creation in low carbon and green industries or enterprises, it is necessary to promote policies which encourage green job standards. On this basis, policies for green job standards should be combined with incentives for enterprise relating to investment, tax and employment. This is necessary in order to promote a greater social awareness of green jobs and low carbon development.

(2) Develop the low carbon service industry and optimize the industrial structure

As the energy dependency of different industries differ, China should develop and expand the share of the tertiary (services) sector in the economy, in particular those services that provide research and development support to manufacturing and consumption service industries and boost domestic demand. Economic sectors which bring high added-value (e.g. eco-agriculture, energy-cropping forestry, and eco-forestry, etc.) should also be supported with a view to achieving the targets of employment creation, increased income and a shift to a low carbon economy.

(3) Encouraging green investment with a priority on creating green jobs

The four-trillion stimulus package is providing some relief to the Chinese economy. However, as most investment flows have been directed to infrastructure programs on transport and construction, such as the building of railways, highways, airports, reconstruction in Sichuan and urban renewal in developing cities, the "carbon lock-in effect" should be taken into account. That means that if the stimulus investment is just a replication of conventional technologies, once invested, there would be a lock-in effect of capital inputs, technology and energy for the lifecycle of the infrastructure item. At present, investment in the green economy related to low carbon development only accounts for only 15% of the total stimulus package. Therefore, to set a solid foundation for a structure-optimized low carbon economy, it is necessary to increase the proportion of investment in green sectors and build a structure that puts employment first.

(4) New green jobs created should be decent

One of the goals of the ILO is to achieve decent employment at the global level. Green jobs are not necessarily those which are decent. Studies show that between 2005 and 2020, the afforestation, reforestation, and forest management sectors will create up to more than 20 million jobs, equivalent to more than one million green jobs annually. However, due to the seasonal and low-tech nature of the industry, the employment opportunities generated tend to be short term and informal, with positions usually filled by migrant workers. Compared with formal working arrangements that include welfare benefits such as social security, these informal forestry-related jobs appear 'green' on the outside, but are not necessarily considered "decent employment."[75] In this regard, improvements to laws and regulations affecting the short-term employment market are needed to: 1) provide the necessary technical training for migrant and laid-off workers; 2) broaden forestry activities to other industrial chains, such as energy-cropping forestry, eco-tourism, the development of forest-related products, and recreational forestry, etc; and 3) increase the ability of workers to find new jobs, improve opportunities for promotion, increase income levels and ensure access to welfare.

(5) Launch pilot programs in selected regions to promote low carbon employment

The move to low carbon employment requires the formulation and implementation of coordinated policies, taking specific industry conditions and regional differences into account. For example, the power generation sector is in the midst of implementing energy-efficiency and emissions reduction measures and is greatly impacted by low carbon development policies. The impact of policy is different for enterprises in electric power and thermal power than in wind and solar power generation. Thermal power enterprises are directly targeted by the policy to phase out inefficient small power units, and as a result, need to concentrate on providing skills training to workers so that they can transition to new positions within the sector. In wind power and other emerging power sectors, demand for technical and management workers outstrips supply of skilled workers. Policies for promoting low carbon employment must be well planned and coordinated with supportive structures such as job training, vocational and technical education, the welfare system, research and development in low carbon technology and technical services to the sector.

As the low carbon economy is a relatively new economic model worldwide, there is little international literature for China to design its transition on. Therefore, carrying out pilot programs in representative enterprises and industries and in selected regions and would be a way to trial the model prior to introduction nation-wide, testing out the impact of policies that support employment as a fundamental part of low carbon development.

[75] China also currently faces the same problems in waste recycling and reuse.

Annex 1: Abbreviations

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: Greenhouse gases

GW: Gigawatt[76]

ILO: International Labour Organization

IPCC: Intergovernmental Panel on Climate Change

kW: Kilowatt

kWh: kilowatt-hour

LCD: Low carbon development

LCE: Low carbon economy

LP: Labour productivity

MW: Megawatt

NDRC: National Development and Reform Committee

NFPP: Natural Forest Protection Program

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

[76] 1 kW = 1000 watts. 1 MW = 1000 kW. 1 GW = 1 million kW.

Annex 2: Fundamental Principles and Data Sources

The study uses the following indicators:

- **Energy Intensity:** The energy consumption 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:** Carbon output or carbon productivity which refers to carbon emissions per unit of GDP.
- **Carbon Cost Effectiveness:** This refers to the costs required per unit of carbon output. For example, while the economic efficiency of thermal power is lower than that of wind power, thermal power is higher taking into account the costs of per unit of carbon output.
- **Carbon Employment Rate:** The CER refers to the labour input per unit of carbon emissions, or the carbon emissions from increases in employment.

The formulae used are as follows:

- **Labour 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 CO_2=$L_i / \sum_1^j (E_{ij} * e_j)$

The term, GDP, used in the above formulae refers to gross domestic product. GDP_i refers to the added value of sector *I*; L refers to the employment number; and *E* refers to the amount of energy consumed. Here, ***i*** refers to sector ***i***, while ***j*** refers to the type of energy ***j***. E_{ij} refers to the carbon emission factor of energy ***j*** in the sector ***i***.

All the research data can be categorized as economic aggregate data, sectoral data, employment data, energy data, and carbon emission data etc. The sources of the data are listed in the following table:

Type of data	Key indicators	Time series	Data resources
Employment	Sectoral employment	1978-2007	CLSY,CPY,CPESY,CESY
	Labour productivity	1978-2007	CLSY,CPY,CPESY,CESY
Energy	The volume of total sectoral energy consumption	1980-2007	CENSY
	Sectoral end-use energy consumption	1990-2006	CENSY
	Fossil fuels, CO2 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 in forest projects, forest coverage, carbon sinks, etc.		CFSY,SFA
	Power sector: installed capacity, etc		SERC, SGCC, CHPG

Comprehensive data	Sectoral energy intensity	1980-2007	Calculated
	Sectoral CO2 emissions	2005	Calculated
	Carbon productivity	1978-2007	Calculated
	Sectoral carbon productivity	2005	Calculated
	Sectoral carbon-employment rate	2005	Calculated

Table 1-1: Data collection and sources

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 Data Analysis

I. Methodology

1. Total Output Multiplier and Impact Coefficient

A. Direct input coefficients and cumulative input coefficients

Assume Xj is the total output of sector j. The 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 “xij ” to the value of total output. i.e., the direct input coefficient can be written as:

$$aij=xij/Xj$$

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

The cumulative input coefficient is noted as bij, referring to the sum of the 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 the matrix of cumulative input coefficient B from the matrix of direct input coefficient A is as follows:

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

B. Output Multiplier and Impact Coefficient

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

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

The output multiplier of a sector shows the degree to which it can contribute to the economy. The larger the value, the more effectively it can promote economic development and create more jobs.

The impact coefficient shows the relative capacity of a sector to induce output. Like the output multiplier, it indicates how the production of one more unit of output in the sector can influence all other sectors in the economy. The equation calculating the impact 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 the Leontief inverse matrix, and $\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \overline{b}_{ij}$ is the average value of the column sum of the Leontief inverse matrix.

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

According to the 2005 National Input-Output Table of the State Statistics Bureau, the output multiplier and impact coefficients of 42 sectors was derived and is shown in Table 1.

Sector	Output Multiplier	Impact Coefficient	Rank
Telecommunications, computing and other electronic equipment manufacturing	4.1887	1.4383	1
Meters, apparatus and machinery for stationery	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 specialized 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 research	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
Poly-technical Services	2.9831	1.0243	23
Processing of Petroleum, Coking, Processing of Nuclear Fuel	2.8843	0.9904	24
Food and tobacco processing	2.8104	0.9651	25
Information transmission, computer services 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
Post & communications	2.6404	0.9067	33
Residential 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	1.8853	0.6474	40
Real estate	1.5588	0.5353	41
Waste products and materials recycling	1.0000	0.3434	42

Table 1: Output multiplier and impact coefficient in 42 sectors
Data source: Calculated by author

II. Direct, indirect and induced employment

The assessment of the employment effect of different sectors is based on analysis theory from the perspective of the supply chain. 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 having a ripple effect through the whole economy. However, this effect will diminish as the economy expands. To evaluate the overall effect of such an expansion on employment, each kind of employment needs to be defined. Direct employment in a sector is defined as the jobs created in the sector which expands manufacturing when output increases; indirect employment is defined as jobs created by the production of inputs in the production process of a specific sector; and induced employment refers to the sum of all other jobs created during the production expansion process.

III. Labour coefficient and employment impact coefficient

Labour 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*. The labour coefficient is an indicator of how output changes affect employment in a specific sector. Thus, we can calculate the **direct employment** created by the increase in output of a sector by this indicator. However, output changes in a sector also induce employment in related sectors. The direct input coefficient shows how one additional unit of product in one sector affects expansion in other sectors. Multiplying increased output in one sector with the labour coefficient of such sector, we can arrive at the indirect marginal employment induced. As a result, we can define **indirect employment coefficient** $\mathbf{I_i}$ as:

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

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

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

In summary, **the total employment effect** per unit change in output can be derived by the formula below:

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

Table 2 shows the labour coefficient and marginal employment effect calculated based on data from the 2005 Input-output Table and from China Labour Statistical Yearbook 2006[77].

Sector	Labour 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 organizations	0.0968	0.0107	0.0132	3
Post and communications	0.0849	0.0113	0.0171	4
Sanitation and social welfare	0.0539	0.0111	0.0236	5
Scientific research	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
Poly-technical 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
Textiles	0.0177	0.0125	0.0247	15
Banking and insurance	0.0350	0.0091	0.0105	16

77 As only data on urban employment was available from China Labour Statistical Yearbook, this paper only examines urban employment.

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
Telecommunications, computers and other electronic equipment manufacturing	0.0084	0.0095	0.0323	20
General and specialised 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 communications	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 trade	0.0281	0.0055	0.0090	33
Accommodation and catering	0.0162	0.0093	0.0159	34
Information transmission, computer services and software enterprises	0.0131	0.0078	0.0183	35
Food and tobacco processing	0.0103	0.0097	0.0163	36
Processing of petroleum, coke, and nuclear Fuel	0.0044	0.0135	0.0174	37
Residential 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
Waste products and materials recycling	0.0141	0.0049	0.0102	41
Real estate	0.0143	0.0046	0.0057	42

Table 2: Labour coefficient and marginal employment effects
Data source: calculated by author

The coefficient in the table shows the number of jobs created with increased sectoral output of RMB 10,000. Using the example of the Residential and Other services sector, the labour coefficient, indirect marginal employment coefficient and direct marginal employment coefficient show for each additional output of RMB10,000, 0.0082 jobs are directly created; 0.0095 job are created by the direct supply of input in production processes; and 0.0166 jobs are created in the overall production expansion process thus creating 0.0342 jobs for all sectors in the supply chain.

Epilogue

This research explores the employment impacts of China's low carbon development strategy on the forestry and power sectors, basic industry, and the green investment component of the economic stimulus package. The research team integrated field investigations with input-output analysis methods to measure the direct and indirect impacts on employment associated with the low carbon economy. The research findings have been approved in principle by experts both in China and internationally, also drawing the attention of policy makers.

Due to the data, time and budgetary constraints, the research team did not extend its research to all the areas of the low carbon economy. While estimates of the impact on employment could be improved in some sectors if more first-hand data was obtained from enterprises, this study provides decision makers with meaningful data on the low carbon economy. The research team hopes that further research will be taken to address the impacts on employment in China in the areas of energy-saving buildings, low carbon public transport, recycling and reuse etc with the methodology of impacts on employment extended to measuring the long term induced effects on the economy.

The research team hope that those interested in the low carbon economy will bring about continuous improvement to both research methodologies and data. Future research into low carbon economy will provide policy support for the promotion of green employment and decent jobs in China.

Green Jobs in China

Green Jobs in China 中国绿色工作

ILO office for China and Mongolia April 2010