

Final Progress Report
Sustainability Science Program
Term: September 1, 2013 – August 1, 2014

Name:
Zhu Liu

Your field:
Sustainability Science

Your degree program, institution and graduation date:
Ph.D. in Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, June 2013

Faculty host at Harvard name and department:
Henry Lee, Harvard Kennedy School

Description of SSP-related research activity, including a title:

A low-carbon pathway for China's sustainable development

Abstract:

This study explores options for a low-carbon pathway for China's sustainable development. Based on state of the art econometric models, this research develops bottom-up energy, water, and emission (including carbon emission and air pollution) inventories, aiming to uncover social and economic driving forces of China's energy and emission growth. New analytical tools and an accounting framework for evaluating energy technology performance are being designed. China's national, provincial, and cities annually energy use, water consumption, air pollution and carbon emissions are being quantified to determine their relationships at the regional and sectoral level. The research assesses the energy saving and emission mitigation potential of key technologies on the basis of an input-output life-cycle analysis model. Social and economic driving forces of energy/emission/water/carbon variations are identified using a structural decomposition model, revealing co-benefits for energy saving and emissions mitigation. Low carbon scenarios based on factors of energy use and emission baseline, energy-water-carbon nexus, technology development, efficiency improvement as well as social and economic drivers are presented.

Identification of the problem you address:

The China's energy and environment issues mainly caused by human activities, can we mitigate the environment pressure by "greening" the activities and achieving low-carbon development?

Key question asked about the problem:

To achieve energy saving and emission control without compromising economic development through development of low-carbon roadmap for China

The methods by which you answered that question:

Coupling "bottom-up" life cycle assessment(LCA) method with "top-down" Input-output (IO) method.

Principle literature upon which the research drew:

Environmental Impact Assessment by using Environmental expanded Input-output analysis model (EEIO) and Life-cycle Analysis (LCA) model.

Carbon emission and carbon footprint calculation

Low carbon scenario analysis by using Computable General Equilibrium (CGE) model

Empirical data acquisition description:

Chinese energy and economic statistics

Geographical region studies:

China

Recommendations that might be relevant for your problem:

To introduce market measure, enhancing regulations, improving technology and promoting international cooperations on the low carbon development for China

A description of the final product(s) you have/are aiming to produce:

1. First author research paper: Titled "A low-carbon road map for China". Published in *Nature* 500 (7461), 143-145. This paper show the pattern and process of China's low-carbon development.
2. First author research paper: Revising anthropogenic carbon emissions. In this research the global anthropogenic carbon emission baselines are revised based on bottom up emission inventory and satellite monitor data. Aim to publish in *Science*.
3. First author research paper: A sustainability accounting framework for China. The paper will asses the impacts of China's economic development, technology development, energy use, water and sources consumption as well as environmental impacts. The impacts will be calculated by using environmental extended Input-output model, and conclude with policy suggestions for achiving sustainable development. Aim to publish in *PNAS*.
4. First author research paper: Carbon emission from China's cities. This paper will take about 160 Chinese cities to develop the carbon emission inventory, and calculate carbon footprint (based on Multi-regional Input-output model) embodied in domestical and international trade. Aim to publish in *Atmospheric Chemistry and Physics*
5. First author research paper: Interpreting China's Unbalanced Carbon Trade. This paper show that China's regions have most unbalanced carbon trade among the world. China accounts for the largest share (34%) of trade-related carbon emissions in the world. the carbon-intensive trade is mainly driven by the high sectoral intensity of China's provinces, implying their low-level technology and fossil-based energy supply. If China improves its export carbon intensity to the level of its imports than China could avoid 1.5 billion tons of CO₂ emission, which is equivalent to the total annual emission of Japan. Efforts on technology and finance aids to reduce carbon intensity and change energy mix for China's regions are urgently needed. Aim to publish in *PNAS*.
6. First author research paper: 4 scopes for calculating regional carbon footprints. In this paper we presented 4 different regional footprint calculation scopes, the results show that regional carbon footprint scopes are related with the regional development level (measured by per capita GDP), the more developed regions in generally have higher scop2, scope 3 and scope 4 footprint when comparing with their scope 1 footprint, which indicated that developed regions trends to have more imports than exports. The research implies the importance of conducting comprehensive footprint analysis for the sustainable development at regional level. Aim to publish in *Ecological Modeling*
7. Co-author research paper: Causes of Stagnating Carbon Intensity in China. This research shows that sectoral efficiency gains in nearly all China's provinces were offset by moving towards a more carbon-intensive economic structure. Such sectoral shift appeared to be heavily affected by a growing role of investments and capital accumulation in China's growth process which favored sectors with high carbon intensity. Panel data regressions show that changes in sectoral carbon intensity were smallest in sectors dominating the regional economy (so as not to endanger these large sectors which were the mainstay of the provincial economy), while scale and convergence effects played a much smaller role. Submitted to *Nature Climate Change* (under second round revision).

Description of major other intellectual or professional advancement activity(ies) over the past academic year, including working titles:

PhD qualifying paper and dissertation:

Spatial-temporal variations of China's carbon emissions

Non-SSP research project paper:

Kuishuang Feng, S. J. Davis, X. Li, D. Guan, L. Sun, W. Liu, Z. Liu, K. Hubacek. Outsourcing CO₂ within China. *Proceedings of the National Academy of Sciences(PNAS)*. 2013, 110(21)

Z. Liu, D. Guan, F. Xi, Tie carbon emissions to consumers (correspondence). *Nature*. (2013) 493, 304-305.

S. Lindner, Z. Liu, D. Guan, Y. Geng, X. Li, CO₂ emissions from China's power sector at the provincial level: Consumption versus production perspectives. *Renewable and Sustainable Energy Reviews*. 19,164-172 (2013).

S. Liang, Z. Liu, M. Xu, T. Zhang, Waste oil derived biofuels in China bring brightness for global GHG mitigation. *Bioresource Technology*, 131, 139-145 (2013).

Please list citations for reports, papers, publications and presentations that built on your fellowship research (please list full citations here, paragraph length abstracts, and attach copies of URLs if possible):

1)Publication:

1. Z. Liu, D Guan, D Crawford-Brown, Q Zhang, K He, J Liu. A low-carbon road map for China. *Nature* 500 (7461), 143-145.
Abstract: Recycling, renewables and a reinvigorated domestic energy market will allow China to lead the world in low-carbon development
<http://www.nature.com/nature/journal/v500/n7461/full/500143a.html>
2. K Feng, K Hubacek, L Sun, Z Liu. Consumption-based CO₂ accounting of China's megacities: the case of Beijing, Tianjin, Shanghai and Chongqing. *Ecological Indicators*, in press, DOI: 10.1016/j.ecolind.2014.04.045 (2014)
Abstract: China has experienced rapid urbanization in the last three decades, with more than half of the population living in cities since 2012. The extent of urban production and urban lifestyles has become one of the main drivers for China's CO₂ emissions. In this study, we focus on the spatial distribution of production activities leading to CO₂ emissions across China as a consequence of final consumption in four Chinese mega cities: Beijing, Shanghai, Tianjin, and Chongqing. Results show that more than 48% of CO₂ emissions related to goods consumed in Chongqing and more than 70% for Beijing, Shanghai and Tianjin occurred outside of the respective city boundary. In addition to the usual focus on efficiency, our analysis adds insights into the causes of CO₂ emissions by looking at the drivers and types of consumption. Addressing consumption patterns in China's cities is critical for China's low carbon development.
<http://www.sciencedirect.com/science/article/pii/S1470160X14001964>
3. D Guan, X Su, Q Zhang, GP Peters, Z Liu, Y Lei, K He, The socioeconomic drivers of China's primary PM_{2.5} emissions. *Environmental Research Letters* 9 (2), 024010 (2014)
Abstract: Primary PM_{2.5} emissions contributed significantly to poor air quality in China. We present an interdisciplinary study to measure the magnitudes of socioeconomic factors in driving primary PM_{2.5} emission changes in China between 1997–2010. Our results show that China's significant efficiency gains fully offset emissions growth triggered by economic growth and other drivers. Capital formation is the largest final demand category in contributing annual PM_{2.5} emissions, but the associated emission level is steadily declining. Exports is the only final demand category that drives emission growth between 1997–2010. The production of exports led to emissions of 638

thousand tonnes of PM2.5, half of the EU27 annual total, and six times that of Germany. Embodied emissions in Chinese exports are largely driven by consumption in OECD countries.

<http://iopscience.iop.org/1748-9326/9/2/024010>

4. S Liang; Z Liu; D Crawford-Brown; Y Wang; M Xu, Decoupling Analysis and Socioeconomic Drivers of Environmental Pressure in China. *Environmental Science & Technology* 48,1103-1113 (2014).

Abstract: China's unprecedented change offers a unique opportunity for uncovering relationships between economic growth and environmental pressure. Here we show the trajectories of China's environmental pressure and reveal underlying socioeconomic drivers during 1992–2010. While absolute decoupling is not realized, China has in general achieved relative decoupling between economic growth and environmental pressure. China's decoupling performance has four distinguishable periods, closely aligning with nation-wide major policy adjustments, which indicates significant impact of China's national socioeconomic policies on its environmental pressure. We observe materialization trends for China's production structure and final demand structure during 2002–2007. Environmental sustainability can only be achieved by timely technology innovation and changes of production structure and consumption pattern.

<http://pubs.acs.org/doi/abs/10.1021/es4042429>

2)Presentation:

Title: China's energy and carbon emissions, presented in course ENVR E-103 Energy: Perspectives, Problems, and Prospects. Oct. 23th, 2013.

Title: Energy productivity in China, presented in course IGA-410 Energy Policy: Technologies, Systems, and Markets. Oct. 9th, 2013.

3)Invited presentation:

Title: Co-reduction of carbon emission and air pollutions. Presented in IGBP workshop, Nov. 5,2013.Denver.

Title: uncertainty of China's carbon emissions. Presented in American Geophysical Union Fall meeting 2013, Dec. 13. 2013. San Francisco.

Please describe any collaborative activities with other SSP Fellows that you are involved with.

Conducted joint proposal: Harvard Colloquium on Innovative Adaptation to Climate Change

Cooperated with SSP fellows Judson Valentim, Pamela Templer, Rachael Garrett and Nigel Asquith

Principal collaborators outside Harvard:

Sai Liang, School of Natural Resources and Environment, University of Michigan

Dabo Guan, School of Earth and Environment, University of Leeds

Fengming Xi, Institute of Applied Ecology, Chinese Academy of Sciences.

Qiang Zhang, Center for Environment System Science.Tsinghua University

List any awards or grants that you have received this year for the current or coming year. Please provide details regarding title of award, financial amount, and date of award:

Title: Best Doctoral Dissertation Award of Chinese Academy of Sciences (CAS).

Date of award: July 7, 2014.

Title : Presidential Award of Chinese Academy of Sciences (CAS).

Date of award: Nov. 17th, 2013

Financial amount: 5,000 RMB plus extra funding if continue to work in CAS.

Introduction: The highest honor of CAS graduates, award 20 students among total 10,000 graduates every year.

Title: 2013 Outstanding volunteer contribution award -Jane Goodall's Roots & Shoots

Date of award: Oct. 10, 2013.

Introduction: Award for outstanding contribution to serve as volunteer of Jane Goodall's Roots & Shoots

<http://rootsandshoots.org/>.