China's Provincial and City Low Carbon Pilot Programs: A New Opportunity for Global Emissions Reductions from "Low Carbon Accounting, Management and Credit System"

By Warren Karlenzig and Daniel Zhu

Introduction

This paper will introduce the main issues associated with successfully achieving low carbon provinces and cities in China, where in 2010 the National Development Reform Commission (NDRC) announced a program for five low-carbon pilot provinces and eight low carbon pilot cities. The NDRC low carbon pilot provinces and cities are expected to lay the groundwork for a national low carbon assessment, planning and management system that should include guidelines for industry, society and the economy—indeed all the energy used in China as well as other forms of national greenhouse gas emissions, primarily carbon. In order to be successful, planning, implementation and ongoing management of such a system should be based on what we are referring to as the "Low Carbon Accounting, Management and Credit System," (LCAMC) which consists of three major elements:

1. **A holistic carbon accounting system within China's five pilot provinces and eight pilot cities based on operational and embodied (life cycle) energy**. The system needs to include a benchmarking of relevant embodied energy, operational energy use and associated greenhouse gas emissions. The analysis would include carbon emissions produced *outside* the pilot provinces or cities for energy or products used *within* the pilot provinces and cities as well as accounting of carbon emissions that are produced *within* the pilot provinces and cities but that are exported for use *outside* the pilot provinces and cities. The low carbon accounting system should also track renewable energy products manufactured *inside* pilot provinces and cities that reduce carbon emissions *outside* the pilot provinces and cities, so that these provinces and cities can be credited for such global carbon emission reductions.
2. **A strategic management system, including performance measures for government at national, regional and local levels**. The management system would be based on a methodology that is currently in successful use in China in more than a hundred well respected commercial organizations.[1] A central component of this methodology is a strategy map, which is a one page graphic illustration of the most important and critical objectives. Strategy maps enable a governance framework and methodology that would ensure strategic directives and processes deployed to successfully develop and promulgate the carbon accounting in #1. This can be achieved in combination with corresponding policy and organizational guidelines (national, provincial and local government, industry, society, citizens), as well as goals and performance indicators. Strategic metrics would include, but not be limited to, energy intensity per GDP. China would need to establish effective communications and education programs both internally among government workers and externally among citizens and businesses for the system to optimize performance in lowering carbon and other greenhouse gas emissions.
3. **An international carbon credit system based on total lifecycle international energy/ product "flows."** With the successful implementation of #1 and #2 on a national basis in China and agreement from other nations (developing and developed nations), an international carbon credit system could provide carbon emission reduction credits for nations that export products used elsewhere, including renewable energy products. The nation exporting products would be eligible to deduct those carbon emissions from their actual total national emissions. Conversely, nations importing products would be assessed with a least a portion of the carbon emissions that were used to produce and transport the imported product, which would be added to that nation's total actual carbon emissions.

The authors believe that China's low carbon provincial and city pilot program can begin to establish the Low Carbon Accounting, Management and Credit System within China that could lead to the success of a full implementation of an equitable international framework for carbon credits. These credits could succeed or supplement the United Nations Framework Convention on Climate Change [UNFCCC] that is currently used by China and other developing nations. The UNFCCC in its current form is set to expire or be changed with the expiration of the Kyoto Protocol in 2012.

Establishing low-carbon provinces or states, regions and cities of scale is an urgent goal worldwide. It is widely held that successful regional or local low carbon assessment and management efforts may be a necessary predecessor to national efforts and international low carbon treaties because they can be

[1] Irv Beiman and Yong-Ling Sun, *Balanced Scorecard and Strategy Execution: Applications in China,* Beijing: China Machine Press, 2009, 2nd ed.

more effectively managed based on regional climate and socio-economic factors, mega-region industry make up, and metro economic clusters. Regional or local low carbon models thus provide a logical progression toward international low carbon accounting and regulatory schemes. Obviously, a global low-carbon economy would ultimately help mitigate global and local damage to economies and civilization. Climate change has been exacerbated by increasing emissions of carbon and other greenhouse gases from industry, government and society, which will need to be decreased by 70-80 percent by 2050—perhaps even by 95 percent--if the world hopes to avoid the most damaging impacts of global climate change.[2]

Current low carbon or "carbon neutral" city attempts include Masdar City, Abu Dhabi (United Arab Emirates); Vaxjo, Sweden; and Vancouver, Canada as well as Rizhao, China.[3] States or provinces, led by California with its Global Warming Solutions Act (or "AB 32") enacted in 2006, have developed aggressive cross-sector carbon emissions reductions plans that support green economic development. In the first half of 2010, for instance, California garnered 40 percent of global clean-technology venture capital, with more than $116 billion in investment. California also led the United States in solar technology patents with 39 percent and in advanced battery patents with 20 percent (California constituted about 12 percent of the U.S. population in 2010).[4]

No nation, however, has embarked upon creating low carbon regions or cities on the scale that China is currently undertaking. Rapid urbanization has precipitated large-scale opportunities including the creation of green economic clusters with "clean technology" or "clean energy" centers: examples include the San Francisco Bay Area, United States; Freiburg, Germany; and Baoding, China. Large scale urbanization has also engendered great risks including the exacerbation of regional pollution and global climate change, particularly if mass urbanization will force higher per capita consumption of resources and energy. Climate change and air pollution are creating increasingly dangerous risks—both predictable and unpredictable--for provinces and metro areas.

Low-carbon provinces and cities can create a ready internal market for the creation, manufacture and deployment of low carbon technologies in buildings, advanced materials, energy infrastructure and transportation, which represent leading economic development opportunities and simultaneous risk aversion strategies. Internal markets alone, however, may not provide sufficient enough economic growth of the clean technology sector, thus exports of such products will need to continue to be part of China's growth strategy. China will need to cultivate its clean technology and other forms of technology know how, which includes creating intellectual capital in the form of patents or monetizable services--both at which California's Silicon Valley has been adept. Renewable energy technology imports and

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[2] "The International Response to Climate Change," The Post Carbon Reader, Richard Douthwaite, The University of California Press/Watershed Media, Healdsburg, CA, October 2010, p. 56

[3] http://www.scientificamerican.com/article.cfm?id=sunrise-on-chinas-first-carbo-neutral-city

[4] "Study Finds California is Global Cleantech Leader," Climate Progress, 11 October 2010, accessed 12 October 2010: http://climateprogress.org/2010/10/11/next-10-study-2010-california-clean-energy-index-cleantech-green-jobs/#more-34725

exports will be increasingly critical to mitigating carbon emissions on a global basis. We foresee that the global market will soon need to be able to account for carbon emissions based not only on country of emissions origin but could also take into account where emissions have been offset because of renewable energy or low carbon product (including carbon sequestration and storage, or CCS) imports-exports. This accounting would facilitate providing international credit to the country of product manufacture.

Urban Areas as Solution Centers for Low Carbon Development

Mega-regions and urban areas, besides being an immense source of problems and challenges, are increasingly being targeted as the world's key source of scalable economic, management and technological solutions, particularly in clean energy and low carbon performance.[5] They are well placed to develop innovative policy solutions that can be scaled up into regional or national programs; they may also be used to provide a laboratory for national pilot programs on the urban level.[6]

A dramatic shift toward scalable low carbon provincial and urban development would provide a means by which to cope with daunting challenges and risks of mass urbanization. During the current profound period of transition from "Business as Usual" (BAU) to low-carbon and more sustainable provincial and urban economies, there will be a need to improve critical system economic synergies by transforming government management and operational approaches, as well as societal behavior. The transformation to a low carbon economy and society is a tremendously complex and difficult undertaking, yet presents global economic opportunity on an unprecedented scope and scale.[7] China's planned economy provides the nation an advantage in terms of setting unified goals and performance measures for a low carbon economy. The provinces and cities in China's low carbon pilot program, moreover, are located near plentiful and relatively low-cost labor, and thus possess a comparative global advantage, particularly when such workers have appropriate management education or workforce training for emergent low carbon economy opportunities.

Looking forward, as China's domestic economy further develops and average incomes increase, the nation's comparative advantage will decrease for low-cost labor compared to less-developed nations. China's dependence on imported materials and products from less-developed nations will increase; the nation is already becoming increasingly dependent on imported fossil fuel energy sources. Fortunately, a provincial and urban low carbon accounting, management and credit system can help provide better energy security for China's economy, government and society compared to the Business as Usual scenario.

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[5] See United Nations' "Shanghai Training Manual for Sustainable Urban Development," Warren Karlenzig and others, to be published 1 May, 2011 by the UN Department of Social and Economic Affairs in conjunction with the National Organizing Committee of Expo 2010 Shanghai China.

[6] "Cities and Green Growth: Issues Paper for the 3rd Annual Meeting of the OECD Urban Roundtable of Mayors and Ministers", 25 May, 2010, OECD Conference Center, Paris, p.11

[7] Ibid, p. 12

Overview of China's Low Carbon Province and City Pilot Program

China's NDRC introduced its low carbon pilot provinces and cities program in summer 2010.[8] The program will be administered by the State Development Reform Committee (SDRC). The five provinces taking part in the pilot project are Guangdong, Liaoning, Hubei, Shaanxi and Yunnan; the eight cities are Tianjin, Chongqing, Shenzhen, Xiamen, Nanchang, Guiyang, Baoding and Hangzhou (Shenzhen is the only low carbon pilot city that is also located in a low carbon pilot province). Together the cities and provinces comprise 36 percent of China's national gross domestic product (GDP), 31 percent of its energy consumption, 27 percent of its energy-related carbon emissions, and 27 percent of the nation's population.[9] The NDRC announced the initiative would cover greenhouse gas accounting, low-carbon development planning, industrial and economic policy, government official training, communications and international cooperation. The NDRC indicated the learnings from the pilot program will be applied to other regions and cities throughout China.

China in 2009 had already announced national operational targets to achieve low-carbon growth, such as reducing carbon intensity per unit of GDP 40 to 45 percent by 2020 from 2005 levels. The nation also set a goal of using 15 percent non-fossil energy as part of primary energy consumption by 2020. The low carbon pilot program marks the first time that national has supported a comprehensive regional-local governmental approach to low carbon performance.

What has not yet been adequately addressed in China thus far is the challenge of *how to develop a comprehensive strategy* for establishing low carbon economic and societal development in China. There are many players and many isolated solutions on offer to Chinese companies and different levels of government. There is much advice and training being delivered to mayors and other officials. Commercial solutions are knocking on many government doors in China. There is, however, no clarity yet at the government level about how to proceed with confidence.

It appears there are three critical missing elements to China's announced low carbon pilot programs:

1. The first missing piece is a way to collaboratively describe, measure, manage and adjust a viable strategy for low carbon economic development at the national, provincial and city levels.
2. The second missing piece is a way to bring multiple parties, subject matter experts and technology solutions together in an integrated and customized manner to fit the circumstances for a particular locale [national, regional, provincial, municipal].

[8] "China Launches Low Carbon Pilot Program in Select Provinces, Cities," People's Daily online, 19 August 2010, accessed 10 October 2010: http://english.peopledaily.com.cn/90001/90778/90862/7110049.html

[9] Zhuang Guiyang, Institute for Urban and Environmental Studies, Chinese Academy of Social Sciences, September 2010: www.unescap.org/esd/...gg.../Session%204_Guiyang%20Zhuang.pdf

3. The third missing piece is a methodology enabling numbers 1 and 2 that can also complement China's participation in emerging international greenhouse gas emissions trading and credit schemes.

As China becomes urbanized (going from 45 percent urbanized in 2010 to an expected 75 percent by 2050), related investments for infrastructure, buildings and transportation systems represent a massive source of *embodied* energy producing carbon emissions during their lifecycle (mining, transportation, production, construction and maintenance) as well as operational energy. Because of these ongoing physical investments, which will in effect be a long-term carbon emission "lock in," China's low carbon pilot provinces and cities should provide a means by which to assess and manage the reduced impact of infrastructure on energy use and carbon emissions. Similarly, the numbers of new urban residents expected to locate in China's metropolitan areas—estimated at 300 and 600 million between 2010 and 2050--will greatly increase energy use and carbon emissions based upon their direct consumption of *operational* energy (heating, electricity, lighting and air conditioning) as well as based on increased consumption of consumer products, including automobiles, appliances, furniture, packaged food and other products, some which will be imported. The increase in private automobile ownership especially is significant. Increased private auto ownership will have implications not only for operational energy use, but will also require additional embodied energy to manufacture, ship and dispose of the cars and to provide accommodating infrastructure including roads, bridges, and parking facilities. Infrastructure can account for 50 percent of the total energy required for a car during its lifetime (including operational energy, or fuel used).[10] Therefore, even if China completely shifts its national private vehicle fleet to electric vehicles that run on solar charging stations, the substantial amount of embodied energy in building vehicles and needed infrastructure could—if not carefully managed--result in large overall national increases in carbon emissions, particularly as the nation's annual auto sales are expected by 2020 to grow by three times the amount of 2009 levels.[11]

Overview Summary

Given this scenario, China's low carbon pilot provinces and cities represent a necessary national shift from attempting to reduce carbon emissions from industry and power generation, to attempting to reduce overall carbon emissions through a more comprehensive approach. Because of its rapid urbanization and societal economic growth, a growing percentage of China's carbon emissions will result from non-industrial sources, including infrastructure development, transportation and residential operational energy use. Traffic congestion in particular represents a major growing inefficiency in China's overall energy use which contributes unnecessary carbon and other pollutant emissions. Traffic congestion makes congested regions more economically vulnerable in terms of both complicating logistics (more difficult just-in-time manufacturing and distribution supply chains) and in the reduction of energy security through the inefficient use of fuel; both negatively impact government, industry and society on many levels.

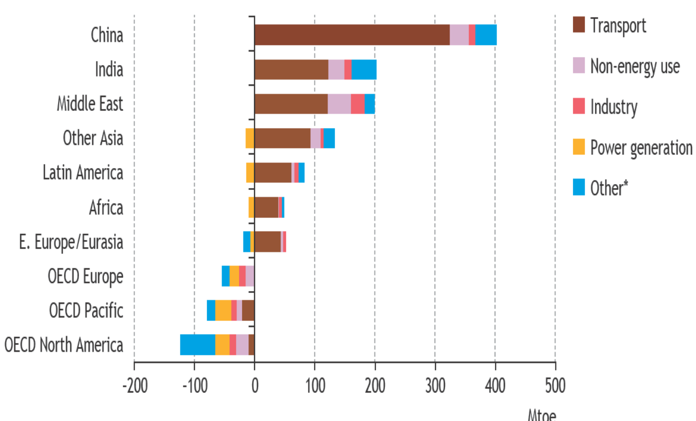
[10] "Watch Your Step: Understanding the Impact of Your Personal Consumption on the Environment," Phillip Camill, National Center for Case Study Teaching in Science, August 2002: http://ublibbuffalo.edu/libraries/projects/cases/case.html

[11] http://www.euractiv.com/en/climate-change/blair-climate-efforts-reason-give-cars/article-184739

Strategy and Planning

Low carbon provinces and cities need to be planned, designed, constructed and managed more strategically than previous development. This is because contemporary low carbon systems and low carbon technologies, compared to the historic development of existing provinces and cities, require special considerations. From a macroeconomic perspective, planning and constructing low carbon provinces and cities is complex. This is because economic models for low carbon technology and services, including financing and pricing, are difficult to forecast and proactively model because of rapidly changing prices for renewable, alternative and conventional (high-carbon) energy. Fossil fuel energy prices will become even more volatile than previous conventional energy sources because of impacts from existing and expected carbon pricing schemes and carbon emission operating permits. These carbon pricing and regulatory schemes will act to mitigate the increasing global climate change caused by urban centers and industrial activity associated with them, including deforestation. Furthermore, periodic or even ongoing shortages of fossil fuel energy supplies, particularly oil supplies, will occur because of a variety of supply and distribution risks including political events (wars, oil embargos or even coal embargos), natural events exacerbated by climate change (hurricanes, typhoons, tropical storms, floods) and accidents or terrorism (refinery, pipeline, oil tanker and drilling rig explosions or leaks from breakage).

Figure 1. Oil Demand in Reference Scenario (2007-2030)



Source: IEA, 2009b

With these potential energy pricing and supply risks in mind and because of the carbon "lock-in" previously described, aligning transport and land use planning with development and control—particularly in establishing viable densities for effective public transport, walkability and non-motorized transportation—should be the current highest priority in low carbon province and city planning and development.[12] The growth of private vehicle use in China (see Figure 1 for International Energy Association oil demand forecast from 2007-2030: "0" represents the forecast base year of 2007) will make the nation more vulnerable to emerging global and national regulations, regional and local air pollution challenges and oil supply interruptions and price volatility. Some good models exist for measuring and modeling effective metro area land use, including those that that measure energy inefficient sprawl.

[12] Managing Asian Cities: Sustainable and Inclusive Urban Solutions, Asian Development Bank, 2008, p. XIII

Recommended land use studies measuring metropolitan areas sprawl include "City Forms, Land Use and Transportation in Chinese Cities"[13] and Smart Growth America's "Measuring Sprawl and Its Impact".[14]

The second area of management concern for low-carbon cities should be the operational energy need for buildings (including residents, offices, schools, hospitals) and industry. This area of energy use and carbon emissions has already been subject to industry performance goals in China, and is well documented with case studies, data and performance-enhancing tools and approaches. The newest currently unprioritized area of concern for low carbon provinces and cities of China is *embodied* energy, which refers to the life-cycle energy used in making products, roads, infrastructure and food. There are emerging life cycle assessment models and data available on embodied energy in cities that will enable low carbon city planning to prioritize analysis and management in this area. Embodied energy is represented by the residential and commercial consumption of household products, food, furnishings, appliances, and water. Embodied energy is also represented in provinces and cities by the construction of new buildings, utility infrastructure, roads, bridges and highways. Using valid data from embodied energy in buildings, infrastructure, products and services, combined with data from operational energy from transportation, buildings and industry, provincial and urban planners can isolate, analyze and better model the critical components for managing low carbon province and city performance.

Low carbon technologies represent in some instances new design and implementation processes that must be combined with more established designs, or systematically integrated to achieve the least amount of carbon intensity. Particular areas of challenge in this regard include storing and transmitting energy from renewable energy sources, because, for example, renewables are currently using inefficient transmission systems developed for centrally located fossil fuel burning energy sources.

Management systems and roles, operational processes, performance benchmarking, feedback systems, use of information and communications technologies (ICT), agent-based modeling and citizen education are also important in the creation of analytical models as well as in controlling development and operations to achieve low carbon provinces and cities.

Models for carbon intensity in the operation of low-carbon provinces and cities, particularly as applied to the use of buildings and transportation, are more established than are models for material carbon intensity (the materials used in buildings and infrastructure). Existing operational carbon intensity models for buildings and transportation systems can be improved significantly as in China they lack sufficient behavioral modeling data based on the actual use of buildings, appliances and transportation systems, which can differ significantly based on climate, user background and training and a number of other cultural factors.

Modeling of provinces and metro areas as a whole for carbon intensity will need to be considered in the development of a low-carbon province or city. Early models combining operational (including behavioral factors) and material carbon intensity using life-cycle assessment are being developed for cities. These

[13] "City Forms, Land Use and Transportation in Chinese Cities", Jin Chen, Beijing Normal University, presented at International symposium, "Realization of Low Carbon Cities", Nagoya, Japan, 2009.

[14] "Measuring Sprawl and Its Impact," Smart Growth America and Rutgers University, 2001: http://www.smartgrowthamerica.org/sprawlindex/sprawlindex.html

models will need to be combined with other metrics including per capita and population or development density measures, plus climate and geographic factors, in order to generate meaningful knowledge of how low carbon provinces and cities can be planned for both new construction and for the rebuilding (or “retrofitting”) of existing cities. A review of some existing low-carbon city measures and rankings from North America and Europe cities will be presented as a background on how such efforts could be leveraged in the development of low-carbon models for the provinces and cities of China.

Embodied and Operational Energy Assessment on the City Level in Suzhou, China

Lawrence Berkeley National Laboratory Study of Embodied and Operational Energy in Suzhou, China

China has been primarily focused on how to reduce the amount and impact of operational energy consumption in the transportation, building and industrial sectors. In additional to analyzing operational energy use in transportation, building and industrial sectors, a 2010 study of Suzhou, China conducted by Lawrence Berkeley National Laboratory for the Institute of Sustainable Communities analyzed energy impacts from embodied energy in materials, buildings, infrastructure, food and other products and services consumed by Suzhou residents, as well as the operational energy consumed by industries, businesses and residents.[15]

China’s cities are expected to gain anywhere from 300 to 600 million people in population over the next 40 years (China’s urban population is expected to reach 1.17 billion by 2050, up from 497 million in 2010, according to the China Sustainable Energy Program.[16]) These residents will need accommodation, schooling, health care, appliances, public and private transportation, food, clothing, water, sewerage, and other services, significantly impacting embodied energy as well as operational energy consumption, all of which will raise per capita greenhouse gas emissions. According to Lawrence Berkeley National Laboratories (LBNL), a typical Chinese urban resident consumes three times as much commercial energy as a rural resident (in total energy terms, rural residents consume more, but the majority is inefficiently combusted biomass, which is often not accounted for in China’s national energy reporting). Planning for the development and maintenance of low-carbon provinces and cities, including developing low-carbon action plans, is a critical step in the nation’s evolution.

The current operational energy consumption of a city alone can lead to conclusions that urban areas, particularly dense urban areas, are relatively energy efficient, largely because per-capita current operational energy consumption is lower than in sprawled urban or suburban land uses, which is typically true. Missing from current measurements of urbanized areas, however, is the amount of embodied energy in the built environment, including not only the buildings themselves, but also

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[15] “Embodied Energy: An Alternative Approach to Understanding Urban Energy Use”, David Fridley, Staff Scientist, Lawrence Berkeley National Laboratory, US Department of Energy, The Oil Drum, August 12, 2010 http://www.theoildrum.com/node/6842

[16] “Sustainable Cities,” China Sustainable Energy Program website, accessed 12 October, 2010: http://www.efchina.org/FProgram.do?act=list&type=Programs&subType=8

pavement, tunnels, bridges, roadways and utilities. Current measures of energy consumption in China also do not take into account the total energy needed to manufacture, transport, and sell products and appliances used in office buildings, homes, schools or retail establishments: furniture, fixtures, paper, electronics, food, packaging, etc.

This means there is a strategic need to examine the energy impact of China's cities from a more holistic perspective that includes the complete built environment, as well as the purchasing and consumption habits of those residing in, working in, or visiting cities. Such impacts can provide valuable additional insight into the true nature of urban energy use.

The energy used in mining, transport, processing, manufacturing, retailing, delivery, and disposal is "embodied" in products including food , electronics, furniture consumer goods and even email. Energy used in constructing buildings and infrastructure from steel, concrete, pavement and wood is similarly embodied in the products from an energy-intensive supply chain of activities. Typically energy consumption is attributed to agricultural, industrial, transportation, commercial, and residential sectors.

Implications

The Lawrence Berkeley National Laboratory (LBNL) approach to examining the energy footprint (which has a direct correlation to the carbon emissions) of a city based on the impacts of the city's inhabitants shows, in the case of Suzhou, that personal consumption of goods and services accounts for the largest (59 percent) contribution to energy footprint of the city, and this figure would likely remain above 50 percent even with inclusion of details omitted in the LBNL model (mainly freight transport, water treatment, and embodied energy of vehicles).

For China's policy-makers, the LBNL Suzhou study suggests that supply-chain issues need to be considered when determining policy and metrics for low carbon provinces and cities. Other conclusions from the LBNL study that can be valuable for low carbon city policy: food appears to be dominant embodied energy use category in Suzhou. Developing long-distance or international food supply chains as in the US would dramatically raise the energy demand and thus also dramatically increase the per-capita carbon emissions of each resident. The LBNL Suzhou study also makes apparent the impact of increasing wealth as rising household income is translated into higher consumption. Similarly, the study suggests that "green buildings" with supposed low carbon or net-zero operational energy may not be "green" at all if the embodied energy of the materials used in the building are considered in the total embodied and operational carbon calculation, which is critically important for a scientifically valid low carbon analysis.

Lawrence Berkeley Laboratories (LBNL) China Energy Group, based in Berkeley, California, developed an analytical model to make calculations on both operational and embodied energy urban energy consumption for a pilot project in Suzhou, China. LBNL is a research laboratory of the US Department of Energy. Suzhou is a city of six million located in the Jiangsu province, west of Shanghai. The project, in support of an ongoing series of training workshops for city officials in China, had a goal to minimize data input requirements in order to make such a tool easy to use. The study incorporated basic data on the city's location, population and households, income and expenditures, building floorspace and building types, infrastructure (road, rail, subway length), and vehicle fleets. From these inputs, LBNL made calculations of current energy consumption and embodied energy use based on energy intensity data in the China End-Use Energy Model at LBNL for the appropriate climate zone. In order to effectively compare results on an annual basis, embodied energy calculations were (where relevant) divided by estimated building lifetimes (e.g. 30 years for buildings is China's current average).

One Suzhou-based company, Shagang, is the world's seventh largest steel producer. Because much of Shagang's steel is not consumed by Suzhou residents, this large industrial component was not considered as part of Suzhou's energy consumption in the LBNL model; instead Suzhou steel consumption (and thus associated energy use) is captured in the infrastructure and building use of steel and in the steel used to make products consumed by the residents, such as automobiles and refrigerators. Similarly, Suzhou residents eat food that is in part not locally grown, but the energy used to produce and transport this food to Suzhou is included in the calculation. This approach enables the modeling of Suzhou energy consumption that is oriented toward the people who are ultimately responsible for its consumption. Therefore, the model excludes energy consumption of those goods and services produced in Suzhou, but are exported from the city and consumed elsewhere.

The Suzhou LBLN study concluded that nearly three-quarters of a total of 111 billion megajoules (MJ) per year in energy used by Suzhou is embodied in the infrastructure and in the consumption of goods and services in the city, while only 26 percent of the energy used is operational energy, or is the energy used to light, heat or cool buildings or to power appliances, such as computers, televisions, and to run vehicles.

Other findings of the LBNL-Suzhou study:

- Suzhou has a car ownership rate of 29 per 100 households, so it is not surprising that among private transportation choices, car energy use accounts for over 70 percent of total transportation energy use.
- The LBNL study determined that the energy used to heat, cool, light, and operate appliances in Suzhou households totals about 11 billion MJ, accounting for about a quarter of the city's total operational energy use.

Measurement of Low Carbon Cities

Cities in North America and Europe have been measured using low carbon indicators based on data and qualitative points of information (see the author's 2007 study, *How Green is Your City? The SustainLane US City Rankings*).[17] These indicators have been obtained from public governmental data (renewable versus conventional energy percentage provided to city, public transit ridership, amount of people walking or cycling for mobility, energy efficiency of buildings) private or non-governmental organization data (third-party certified green buildings per capita, urban sprawl factors) and from primary survey research (city low carbon plans, low carbon management systems, city low carbon projects). These rankings have provided an overall city sustainability, low carbon, or environmental performance "report

[17] *How Green is Your City? The SustainLane US City Rankings*, Karlenzig, Warren, et al., New Society Publishers, Gabriola Island, Canada, 2007. Also see "European Green City Index," December 2009: http://www.siemens.com/innovation/en/publications/publications_pof/pof_spring_2010/green_cities/egc_index.htm

card" for public officials, media, civic organizations, foundations, industry and citizens. In addition to providing an overall performance ranking through the aggregation of individual category rankings, non-aggregated category rankings provide more specific information that could be useful for China in developing its low carbon provincial and city pilot programs. The most relevant rankings might include total per capita CO2 production and per capita energy consumption, production, renewable energy percentages (as well as fossil fuel percentages) used by each city and transportation statistical rankings, such as percentage of provincial or city public transportation ridership, and percentage of provincial or city residents walking or bicycling to work.

Planning and Developing Low-Carbon Society

Besides acting as centers for economic activities which need to be systematically managed in order to optimize low carbon performance, provinces and cities consist of other vital factors: the inhabitants. If residents are educated about the best choices for reducing carbon footprints, some, perhaps many, will be willing to engage in behavior to reduce their carbon emissions. Even if residents do not choose to change behavior voluntarily, provinces and cities can effect large-scale greenhouse gas-reducing behavior change through mandates, incentives, system improvements and public information campaigns, particularly in areas such as transportation use, consumption of products, waste production and home or office energy use.

Local populations of provinces, metro areas and cities make numerous choices directly and indirectly impacting overall province and city low carbon performance, including:

- Where to live: location of residences, jobs and shopping and entertainment choices have substantial impacts on the carbon footprint of a province or city--how close a residence is to amenities that can be reached by walking, bicycling or public transportation is a factor influenced both by urban master planning, business and real estate development and the choices made by citizens.
- One major choice that a citizen makes or that policymakers set that reduces lifetime carbon emission impact is to limit family size by having or requiring a lesser number of children or no children.
- Another important resident choice is how large and what type of structure people will live in: the quantity and type of material used in residential building construction has significant embodied energy implications. Standalone homes use the most embodied and operational energy, mainly because they lack common walls; utilities and infrastructure; plumbing; and insulation that multi-family residents share.
- Other important citizen behavior-dependent qualities include what type of energy use residents' homes and businesses require through heating, cooling and use of electricity. How citizens choose to operate and maintain automobiles, appliances, fans, window shades, landscaping and water use are also important factors impacting a provincial or city carbon emission profile.
- The final area in which citizens impact their city carbon footprint is the types of food and household products they purchase and consume. Products or food with minimal or low-impact packaging (reusable packaging or non plastic or less resource-intense packaging, such as newspaper, straw, etc.) or products that are produced locally or regionally, generally have much less of a carbon footprint than heavily packaged (PVC wrapping, foil, thick plastic, foam) products. Food items that are imported from long distances on airplanes, trucks or large boats require major amounts of

embodied energy for production and transportation. Food items imported long distances also may require refrigeration or special energy intensive gases for sterilizing, ripening, etc. Types of foods produced and consumed have a major embodied energy impact on greenhouse gases. The global production of meat, for instance, produce 14 to 22 percent of global greenhouse gases each year, with beef accounting for 13 times more global warming impacts than chicken. Thus if China's citizens more to a heavier meat- and particularly beef-based diet, global greenhouse gases will increase accordingly.[18]

Regional Green Industry Development

Regional supply chains and knowledge acquisition or retention are important considerations in the establishment of provincial or metro clean technology or clean energy clusters. Centers of clean tech knowledge and innovation need to be able leverage regional educational institutions, information technology and national investment strategies made according to regional workforce characteristics. Similar to traditional industries, geographic considerations for regional green economies includes presence of transportation infrastructure (rail, ports). Even more than traditional industries, green economic considerations are based upon development of investment, education and innovation communities, as well as supporting financial mechanisms, including loans and subsidies, land grants, and special empowerment zones.

Low carbon provinces and cities represent a special advantage for the production of clean energy technologies, as urban regions or mega-regions can gather together a critical mass of people with highly specialized and advanced skills that have the ability to engage in particular productive activities. Mega-regions and metro regions also constitute a broad location where a large number of different people with a wide range of highly diverse specialized skills mix together. This aggregation allows provinces or urban areas to become both very productive and particularly innovative in developing and marketing new products and new production processes that combine knowledge from different, previously unrelated, disciplines in the creation of new industries, which may or may not have been anticipated or planned.

Additionally, in terms of initial demand for clean energy technologies, provinces or metro areas can be important "customers", providing a ready-made market and need for these products and services. Provinces and cities, their local government workforces and local energy utilities constitute an effective means by which to test or pilot new clean energy technologies or services being researched by regional green industry clusters, and are thus able to provide rapid feedback.

Knowledge should also be actively "imported" from other global or regional centers of excellence (universities, clean tech industrial clusters). Regional education and innovation institutions require complementary resources outside the region through knowledge transfer, including exchanges and sharing of best practices, strategic frameworks and low carbon modeling and assessment.

[18] "How Meat Contributes to Global Warming," Nathan Fiala, Scientific American, 9 February 2010: http://www.scientificamerican.com/article.cfm?id=the-greenhouse-hamburger

Clean energy development for low-carbon provinces and cities (renewable energy, alternative fuels) must be accompanied by technology innovation enabling the more efficient use of fossil fuels. Even under the most optimistic of renewable energy use scenarios, coal and oil will account for 55 percent of the China's primary energy mix in 2050. Other estimates predict by 2050 China will require at least 45 percent coal energy. The practices of making more use with less oil and coal in particular will be as important as or will be even more important than China's efforts in developing renewables, nuclear, and natural gas.[19] Coal carbon sequestration and capture technologies also need to be part of a balanced portfolio for the development of low carbon provinces and cities.

Next Steps

Low Carbon Accounting, Management and Credit System Proposed for China's Low Carbon Pilot Provinces and Cities

The authors propose that China utilize a strategic approach for planning low carbon pilot province and city development starting with an analytical approach assessing carbon emissions based on operational and embodied use. This assessment would include mapping import-export product trade and energy flows between provinces and cities so that strategic plans can be made to both reduce provincial carbon emissions and to subtract or add carbon emissions credits from each province's or city's total actual emissions. In support of such activities, the authors propose a strategic framework that would guide government policy, industry, businesses and residents. If successfully piloted on a provincial or city level, the Low Carbon Accounting, Management and Credit System (LCAMC) could then be applied as the basis for provincial and urban policy throughout China. By successfully modeling China's operational and embodied energy use and flows between provinces, including product imports-exports, China would be able to propose an international carbon accounting system whereby China and other nations could receive carbon reduction credit for exports of products used in other nations (especially renewable energy products, which would in effect receive "double" credit for the emissions they offset and for the emissions created during their manufacture). Conversely, China and other nations that import products, including renewable energy products, would need to add to their own carbon emissions "account" the life cycle carbon used to manufacture, and possibly transport, the product.

Low Carbon Accounting, Management and Credit System Applied to Example of Baoding, China

An example of how a Low Carbon Accounting, Management and Credit System (LCAMC) could be applied to China can be illustrated with the NDRC low carbon pilot city of Baoding. Baoding, a city of one million about 100 miles southwest of Beijing in the Hebei Province, the city has ascended rapidly as a working urban model of China's world-leading clean energy economy.[20] Within four years Baoding's economic growth rate surpassed that of all other cities in the heavily industrialized province--its strong performance has been linked to a 40 percent growth rate in companies producing low-carbon technologies. These companies include almost 200 producers of wind, PV and thermal solar, biomass, and energy efficiency technologies. As of 2010, approximately 20,000 Baoding jobs have been created in clean energy, including 7,000 jobs at Yingli Solar, one of the nation's largest PV solar producers, with

[19] "China's Clean Energy Push", Memo, Center for American Progress, Washington DC, June, 2010

more than $1 billion in fiscal 2009 revenues. Baoding's combined companies in 2008 sold 500 megawatts (MW) of solar products and 5089 MW of wind power products.[21]

After China's national government in 1992 established the Baoding Industry High-Tech Development Zone,[22] Baoding Mayor Yu Qin began researching clean energy technologies through visits to nations with early-stage renewable industries in Europe. Baoding decided it would also emulate the industrial cluster model of California's Silicon Valley, but instead of semi-conductors and software, the city began to create what it calls "Power Valley." Said Mayor Yu Qin, "Polluting first and paying later is very expensive. So we chose renewable energy to replace traditional industry."[23] Baoding area companies and the city were able to secure bank loans with interest rates as low as two percent—the result of a government policy of steering loans toward renewable energy investments.[24]

Exports are essential to bolstering the Baoding's local economy: one company makes turbine blades for wind farms in Texas (United States), while another company supplies solar panels to Portugal for what is currently one of the largest solar power stations in the world. By one account, the city may be among the world's first to go "carbon positive."[25] This would mean that the carbon emissions saved annually worldwide through the use of equipment made in Baoding would outweigh the city's own greenhouse gas emissions.[26]

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[20] "China is leading the race to make renewable energy," Keith Bradsher, *New York Times*, 30 January, 2010. http://www.nytimes.com/2010/01/31/business/energy-environment/31renew.html

[21] "China to Develop Low Carbon Cities," *People's Daily*, 12 October, 2009 http://english.peopledaily.com.cn/90001/90776/90882/6781237.html

[22] Baoding Industry High-Tech Development Zone website: http://www.bdgxq.cn/english/gqgk_eng.asp

[23] "The World's first Carbon Positive City will be in…China? The Mayor of Baoding Is on a Crusade to Make It a Hub of Renewable Energy", Peter Ford, *Christian Science Monitor, 16* August 2009. http://www.csmonitor.com/Innovation/Energy/2009/0810/how-baoding-china-becomes-world-s-first-carbon-positive-city

[24] "China is leading the race to make renewable energy," Keith Bradsher, *New York Times*, January 30, 2010. http://www.nytimes.com/2010/01/31/business/energy-environment/31renew.html

[25] "Reinventing the City: Three Prerequisites for Greening Urban Infrastructures" WWF International (in conjunction with Booz & Company), Gland, Switzerland, 2010: http://www.slideshare.net/itsgowri/wwf-low-carboncities

[26] "The World's First Carbon Positive City will be in…China? The Mayor of Baoding Is on a Crusade to Make It a Hub of Renewable Energy", Peter Ford, *Christian Science Monitor,* August 16, 2009. http://www.csmonitor.com/Innovation/Energy/2009/0810/how-baoding-china-becomes-world-s-first-carbon-positive-city

Yet, despite the obvious progress Baoding has made in terms of low carbon economic development, Baoding's greenhouse gas emissions and energy intensity per GDP have risen on a per-capita basis.[27] Baoding and other such "carbon neutral" or "carbon positive" cities or regions should be eligible not only for international recognition, but also for a form of international carbon credit the authors propose that accounts for and credits total contribution to global carbon reductions through clean energy export technologies. Once such a system is in place, it can be carried up to the national level not only for renewable energy product exports but for products of all types. Baoding should be able to offset the carbon emissions from its manufacturing that will be saved in both domestic (other provinces in China) and exported clean technology that is deployed outside of China to reduce global carbon emissions. In the case of both other provinces and other nations using Baoding's clean energy technologies, they should add the carbon emissions that occurred from manufacturing the clean energy technologies in Baoding to their own carbon account. Such an approach would require that China would need to balance its carbon accounts internally first—through a nation-wide provincial carbon accounting practice based on this approach. Once this was achieved on a national basis with verifiable third-party certification, China could reconcile its growing role in manufacturing global solutions for greenhouse gas reduction in clean energy, transportation and other technologies: the country's high-speed trains, for instance, might be exported to countries including the United States, which is planning its own high-speed rail network.[28]

Thus China's low carbon pilot provinces and cities could use the Low Carbon Accounting, Management and Credit System that would result in a more equitable international accounting and credit system for not only greenhouse gas emissions, but also for technologies that reduce greenhouse gas emissions, either directly (solar and wind energy technologies), indirectly (high-speed trains) or through carbon sequestration (carbon capture and storage).

The steps required for the proposed LCAMC have been identified by the Institute for Strategic Resilience and include the following:[29]

1.1 Integrate Provincial and City 12th Five Year Plans with Provincial and City Low Carbon Development Planning.

Key objectives, targets and timelines for both Provincial and City plans need to be integrated across the two government levels for the more traditional centralized plan [12th Five Year Plan] and the desired strategic low carbon plan. Project teams from these two government levels would need to collaboratively integrate the two plans. The output deliverable from this guided collaboration will be one or more strategy maps and balanced scorecards that clarify the objectives, measures, targets and key initiatives. *Strategy maps* are

[27] "Reinventing the City: Three Prerequisites for Greening Urban Infrastructures" WWF International (in conjunction with Booz & Company), Gland, Switzerland, 2010: http://www.slideshare.net/itsgowri/wwf-low-carboncities

[28] "China: a future on track?" Jamil Anderlini, *Financial Times, China*: 8 October 2010: http://www.ftchinese.com/story/001034854/en

[29] The following section is adapted from a 2010 draft proposal by the Institute for Strategic Resilience (www.isrchina.org) developed in response to a request from the Shaanxi Province by ISR's Irv Beiman, Daniel Zhu and Warren Karlenzig

one page graphic illustrations of strategic objectives, organized into strategic themes and perspectives. Strategy maps will be used to generate alignment and a common understanding of the key objectives across plans for both government levels. Balanced scorecards will be used to clarify how objectives will be measured, as well as performance targets on the key metrics. Scorecard development will also include identification of likely key initiatives for action, a key aspect of *implementing strategy,* by ensuring clarity of objectives, measures, targets and initiatives.

1.2. Establish research investigation for local measurement and data collection.

China will need to coordinate and support the relevant resources and subject matter experts to develop a high-level baseline measurement of operational **and** embodied carbon emissions by:

a. sector (industrial, agriculture, forestry, service, residential, building),
b. product (commercial and residential), and
c. activity (manufacturing, land use and planning, transportation, water and food energy use, product and material recycling or reuse, product and material disposal).

1.3 Clarify a new strategic framework for integrated Five Year and Low Carbon planning to establish new patterns of thinking.

To repeat [from1.1], *Strategy maps* are one page graphic illustrations of strategic objectives, organized into strategic themes and perspectives, with hypothesized causal relationships illustrated through arrows connecting the different objectives. A strategy map template can be used to help provincial and city officials customize their strategic objectives according to local conditions and circumstances. High level executive training on the use of this and others tools for describing, measuring, managing and adjusting provincial and city level low carbon strategy implementation would be needed. This executive training would enable government officials to understand how they can use this methodology to create *clarity, focus* and *alignment* across multiple government agencies and organizations. The purpose is to accelerate progress toward achieving low carbon objectives. This is the *management component* for achieving low carbon economic development. This management component should accelerate the integrated deployment of technology solutions, as well as policy adjustments and capital flows for funding.

1.4 Develop comprehensive guidelines for advanced planning.

China would need to cascade provincial and city level strategy maps [strategic objectives, measures, targets & initiatives] to lower levels of the respective government organizational structures.

1.5 Cascade the integrated Five Year and Low Carbon plan to local industry for *optimizing* energy structure

China would need to cascade government plans into strategically selected industries and enterprises. Based on energy/carbon analysis in Activity 1.2 (above) this could include strategies and actions related to local industry product and energy imports and exports and the resultant provincial or city carbon emission impacts. Products or energy *exported* for use outside a province or city (“Province A or City A”), but producing carbon emissions in Province

A or City A during manufacture, should eventually be discounted from Province A's or City A's total carbon emissions. Province A or City A's carbon emissions would be adjusted downward to reflect exports of products or energy consumed in other provinces (Province B) or nations. Similarly, Province A or City A's *imports* of energy or products (and associated greenhouse gases) from Province B or nations should be adjusted upward as part of Province A's or City A's carbon emissions account even if products or energy is produced in Province B or another nation but is consumed in Province A or City A. In relation to the low carbon development strategy, the industry energy structure will accelerate low carbon technology innovation, promoting low-carbon technology development and industrialization, as well as the planning of low-carbon technology to upgrade traditional industries, and accelerate the development of low-carbon urban planning, infrastructure and the built environment. This could draw upon the latest technological, management and societal advances in low carbon development and actively promote technology adaptation and innovation, including joint research and development with foreign countries.

1.6 Improve the efficiency of energy consumption and fossil fuel use in the economy.

Improving the energy efficiency of fossil fuel use for China is critical as China will still be dependent on coal for at least 45 percent of its power by 2050, even with added renewables .[30] This step overlaps with 1.2 and 1.3, for adjustments in Policy and Industry Structure, respectively. It may be possible to conduct pilot tests, including carbon capture and storage (CCS), to determine where the desired efficiencies can and cannot be achieved, and incorporate those results and analyses into 1.2 and 1.3 for more widespread strategic impact.

1.7 Improve financial credits for carbon emission reductions and product exports (embodied energy credits), particularly renewable energy technologies

The Kyoto Protocol is set to expire at the end 2012. Kyoto includes the Clean Development Mechanism [CDM]. This is a financing mechanism governed by the United Nations Framework Convention on Climate Change [UNFCCC] that is currently used by China and other developing nations. It is also set to expire or be changed. China's continued access to international carbon financing is likely to be linked to its willingness to take on increased greenhouse gas mitigation actions. Several options under consideration for reforming the current structure of the CDM or eliminating CDM as part of a post-2012 international climate treaty might impact renewable energy development in China for many years. The relevant question for the future of the CDM is how it can be better structured such that developing countries such as China are still encouraged to promote renewable energy development in a more direct and effective manner. The UNFCCC estimates that global additional investment and financial flows of $200 to $210 billion annually will be necessary by 2030 to return global greenhouse gas (GHG) emissions to current levels, and that an additional $100 billion per year will be needed to de-carbonize developing countries. A proprietary system combining low carbon energy benchmarking (1.2 above) with carbon credits and financing that is based on China receiving carbon emissions reduction credits for: 1. Greenhouse gas emissions produced

[30] Author email correspondence with David Fridley, Staff Scientist, Lawrence Berkeley National Laboratory, Berkeley, United States Department of Energy, 9 August 2010.

through the primary manufacture of products that are exported for use or consumption outside China; 2. Clean energy products primarily manufactured in China (wind turbines, PV solar arrays, etc.) that reduce greenhouse gas emissions outside China. China and other developing nations would be eligible for greater weighted credits, depending on the amount of carbon reduction achieved through out-of-country use.

1.8 Clarify action initiatives, prioritize tasks and develop specific measures for regional GHG emission control, for the purpose of reducing carbon emission intensity

Carbon emission intensity is China's single most important strategic measure for low carbon performance. This objective and measure should be decomposed into subsidiary objectives and measures and then cascaded down through layers of provincial and city government. This can be accomplished through the use of strategy maps and balanced scorecards, combined with expert resource advisory on the technical issues associated with effective detailing of subsidiary objectives and measures. This objective set, focused on carbon emission intensity, will be cascaded into management of provincial and city activities (transportation, construction, resident and business use of products and services), as well as to strategically targeted industries, with the purpose of continuing to reduce carbon emission intensity. Other metrics may need to be devised in conjunction with carbon emission intensity for sectors (i.e., transportation and residential) that do not directly produce economic outputs.

Other Key Objectives for Low Carbon Accounting, Management and Credit System (AMCS)

Set up Policies that are aligned with green development objectives.

China should investigate new policies as well as adjustments to current policies, based on the insights and learning achieved during the above steps 1.1 – 1.8. China would need to identify third party resources to propose and adjust key policies based on international best practices. The purpose is to support the effective achievement of green development objectives. Strategy maps, causal relationships and scorecard measures could be useful in this adjustment process.

Establish industrial system for low carbon emissions.

Objectives would need to be cascaded to lower levels of government and to targeted industrial sectors. As targeted companies in those sectors develop their own objectives, measures, targets and initiatives, this entire process could stimulate the "birthing" of a *low carbon industrial system.* That system can be managed through adaptation of the strategic governance activities that have been established in the commercial sector on an enterprise basis. There should be multiple elements in this industrial system, including: strategy execution components and tools, innovative technology resources in targeted sectors, measurement and tracking systems to examine the complex inter-relationships across government, industries, land use and transportation, and an industrial governance system to incorporate lessons learned for improved performance. The development of this industrial system may influence the adjustment of existing industry structures, and may birth new structure(s) that are focused on achieving national, provincial and city level goals for low carbon emissions.

Build the statistical data system and management system.

China would need to develop a complete pilot information and a data management system for greenhouse gas emissions that could accommodate future data iterations. This should include the development of key indicators as outputs: i.e., energy intensity per capita and a complete model of energy inputs on provincial and/or city scale to achieve most effective policy and development prioritization

Promote the low carbon green lifestyle and model for consumption.

Training would need to be provided for all levels and all departments of leaders to enhance attention, awareness and communications about climate change, to encourage low-carbon management, low carbon lifestyles and behavior (including operational and embodied energy—i.e. product and service—consumption), promote the use of low-carbon products and services, demonstrate the concept of low-carbon life, and promote broad participation of all the people. China and its low carbon provinces and cities would need to develop public outreach (media campaigns) for business and citizens as well as internal communications campaign for public officials.