COMMENTARY

High Tech's Toxic Legacy in China

By Jamie Choi

The modern world is full of electronic products, many of which are quickly outdated and replaced by newer, supposedly improved, models. Thus, it is not surprising that electronic waste (e-waste) has become the fastest growing component of the municipal solid waste stream. The United Nations Environment Programme (2004) estimates that between 20 and 50 million tons of e-waste are discarded annually worldwide. While developed countries generate the overwhelming majority of e-waste, it is developing countries that must bear its environmental and social burden.

China has a unique position in the e-waste dilemma, for it both manufactures and dismantles the majority of electronic products. While e-waste scrap yards can be found in many countries throughout Asia, Africa, and Latin America, it is believed China receives over 70 percent of the world's e-waste (Basel Action Network, 2002). In recent years, domestic consumption of electronic products has dramatically increased in China and since 2003, the country has generated roughly 1.1 million tons of e-waste annually (Li Yanbo, 2005). While China has begun to play the role of e-waste producer, it remains far behind the United States, which generates approximately 5 to 7 million tons of e-waste annually (Basel Action Network, 2002).

E-waste is a problem not simply due to its sheer quantity, but also its toxicity. Modern electronics contain many hazardous materials, which makes dismantling e-waste a difficult and dangerous task. The environmental and health problems arising from e-waste dismantling are enormous and are mainly borne by developing countries, particularly Chinese scrap yard workers and surrounding communities.

TRANSBOUNDARY MOVEMENT OF E-WASTE

Why do developed countries not process their own e-waste? The answer is simple: the process is both expensive and labor-intensive. Waste companies can instead earn a profit by selling e-waste to brokers in developing countries.

Recycling companies in developed countries strip e-waste of its most valuable parts before shipping it to brokers in developing countries. In China, containers packed with e-waste are smuggled predominantly into ports located in the south, where they are stored in warehouses before being shipped to scrap yards throughout the country.

The transboundary movement of e-waste is often justified in the name of "recycling," a misleading phrase, for it is impossible to safely or effectively recycle many hazardous e-waste materials. E-waste "recycling" is done primarily in small towns where environmental and workplace regulations are lax and expertise on safe dismantling is sometimes nonexistent. Improperly-handled e-waste toxins harm workers and pollute the environment.

SO HOW TOXIC ARE ELECTRONIC PRODUCTS?

Electronic devices are a complex mixture of several hundred materials and components, which often contain a variety of toxic substances such as lead, mercury, cadmium, beryllium, brominated flame retardants, and polyvinyl chloride (PVC) plastic. These toxins can have a wide range of negative health effects, including suppression of the nervous system, endocrine disruption, respiratory and developmental problems, liver damage, cancer, and

Guiyu's mountains of electronic components grow higher, highlighting the failure of the government's ban to stem the flow of e-waste into China. Photo Credit: Greenpeace China

damage to reproductive systems. Scientists found large quantities of these toxins in both the water and soil of e-waste dumpsites (Greenpeace Research Laboratories, 2005).

GUIYU: THE HAZARDS OF E-WASTE DISMANTLING

In recent years, the town of Guiyu in Guangdong Province has gained international notoriety as one of the largest e-waste dismantling centers in the world. Until the 1980s, Guiyu was a small rice-growing community. Over the past two decades, Guiyu has rapidly metamorphosed into a booming e-waste processing center. While some rice farms still exist, virtually all the available land in Guiyu is occupied by thousands of e-waste dismantling yards. It is estimated that Guiyu now has some 2,500 computer-dismantling businesses. The labor-intensive nature of e-waste dismantling has drawn hundreds of thousands of migrant workers from all across China to work in Guiyu.

In Guiyu, the word 'recycling' quickly loses its meaning. Workers burn the plastic coating from copper wires over open flames, brush carbon black toner from printer cartridges into a bucket, melt lead solders[1] over hotplates in workshops ventilated only by a small fan, and dip circuit boards into open vats of concentrated acids. Protective clothing usually only involves cotton gloves. In my visits to Guiyu, it was not uncommon to spot children, some as young as four years of age, stripping copper from cables and wires, smashing computer chips with hammers, or plucking valuable metals from shattered components.

The e-waste dismantling industry's impact on the environment is palpable. As one enters Guiyu, the smell of burning plastic fills the air—even people from nearby towns complain of the smell. The streams running through and around Guiyu are black. A water sample taken in 2002 revealed levels of lead 190 times higher than the drinking water standard set by the World Health Organization (Basel Action Network, 2002). In the mid-1990s, Guiyu residents began to notice that the water had an abnormal taste, so water began to be imported from Ninjing, a town 30 miles away. However, workers can still be seen using the black-colored water to wash vegetables, dishes, and clothes.

In a 2005 report of industrial wastes, dusts, soils, river sediments and groundwater contamination in Guiyu, Greenpeace discovered high levels of lead,

tin, copper and cadmium, as well as pollution from organic chemicals used in the electronics industry. For example, dust collected from a solder recovery shop contained levels of lead hundreds of times higher than those typical of indoor dust. Persistent organic pollutants (POPs) were also commonplace, including the highly toxic and bioaccumulative polychronated biphenyls (PCBs) and polybrominated diphenylethers (PBDEs) (Greenpeace Research Laboratories, 2005).

Impacts on people's health are as conspicuous as environmental degradation in the area. In 2005, the Medical School of Shantou University conducted blood tests and health checkups of Guiyu's e-waste workers and children. The results were shocking—of the 165 children between ages 1 and 6 who were examined, 81.6 percent showed symptoms of lead poisoning. Moreover, 88 percent of the workers suffered from skin diseases or had developed neurological, respiratory or digestive ailments (Peng Lin, et al., 2005).

In private interviews with Greenpeace China, many dismantlers complained of respiratory difficulties, stomachaches, headaches, and skin problems. When asked whether they knew if dismantling e-waste was bad for their health, one laborer responded: "Of course we know. But what can we do? We have to make a living."

These workers earn between $1.5 and $4 a day—meager salaries by Western standards, but much more than many can earn from farming. Ultimately, e-waste trade forces Guiyu's workers to choose between their health and making a living

REGULATIONS TO STEM E-WASTE TRADE

Governments around the world have slowly begun to rise to the challenge of the harmful impact of e-waste. In an effort to curb the unjust trade of hazardous wastes, the Basel Ban Amendment to the Basel Convention, which prohibits the export of hazardous waste from OECD to non-OECD countries, was ratified in 1994, but has not yet entered into force. Most developed countries as well as some developing countries, including China, have ratified the ban. The United States remains the only major e-waste exporter that has not ratified the Basel Convention (or the Basel Ban Amendment), thereby making it legal for U.S. recyclers to continue exporting hazardous e-waste to the developing world. It is estimated that somewhere between

> **"Of the 165 children between 1 and 6 who were examined [in Guiyu], 81.6 percent showed symptoms of lead poisoning.**

50 to 80 percent of the e-waste collected in the United States is exported for disposal (Basel Action Network, 2002).

The Basel Ban is not the only recent regulation addressing the issue of e-waste exports. In 2006, the European Union adopted another law, the Restriction on Hazardous Substances Directive (RoHS), which prohibits the use of six hazardous substances—including mercury, lead, cadmium, hexavalent chromium, and the toxic flame retardants PBB and PBDE—in all electronics sold in the EU. The EU, Korea, Japan, Taiwan, and several states in the United States have also introduced take-back legislation making electronic manufacturers responsible for the ultimate disposal of their products.

Countries at the receiving end of e-waste exports, such as China, also have enacted their own sets of legislation to tackle this problem. In 2000, the Chinese government banned the import of e-waste. In 2003, the State Environment Protection Administration issued a notice banning outdoor burning of e-waste components and the practice of acid bathing PCB boards. Finally, in March 2007, the Ministry of Information Industry put into effect its own China RoHS directive, similar in content to the EU RoHS. To date, the creation of safe e-waste treatment facilities has been limited:

- Beijing municipal government established China's first registered e-waste facility, the Beijing Jin Huan Industry Waste Treatment Service Station, in 1996.

- Beijing's Haidian District, home to many of China's top technology companies and universities, initiated the Electronic Environmental Protection and Recycling Economy project and licensed the first activities in four test sites in April 2006. The four sites are located at Zhongguancun Repair City, BUAA Business Incubator, Yuga International Resources Cyclic Utilization Company, and Red Tree Company.

Each site manages different tasks in the processing and recycling of goods. Zhongguancun Repair City is the site for electronic waste drop-offs. BUAA is responsible for dismantling and processing the waste, particularly electrical panels. Yuga is in charge of processing the plastic packaging and Red Tree handles other waste like used batteries.

- Jiangsu Province's first e-waste dismantling facility, built by Singapore's Citiraya Industries, opened in Wuxi at the end of 2004.

- Tianjin has one e-waste facility, built in 2005 by Taiding (Tianjin) Sci-tech Environment Protection Company.

- Shanghai opened its first e-waste facility in April 2007. The facility is called the Xin Jin Hua Old and Waste Electronic and Electrical Appliance Recall Center and it covers Changning District only. Sometime in 2008 the Shanghai Municipal Development and Reform Commission may form an e-waste recall network covering all the nine key districts of Shanghai, which will include a hotline for the citizens to book a collection service to come to their homes to pick up used goods.

While the government has taken these important first steps, in practice little has changed. Firstly, RoHS regulations cover only a fraction of the hazardous chemicals in use. Moreover, the regulations prohibiting the import of e-waste are easily circumvented through payments to corrupt border officials or simply smuggling into the country. The regulations to make e-waste dismantling safer are oftentimes ignored, and the e-waste dismantling industry throughout the developing world continues to be largely unregulated. Without strong and consistent regulatory pressure, progress throughout the sector will remain slow.

PROMOTING BROADER STAKEHOLDERS IN THE SOLUTION

It is clear that government regulations are not sufficient to fully halt the import of illegal waste so long as it remains a highly profitable business. Thus the need to find safer ways to disassemble, recycle and store old electronic products has become all the more critical. Organizations such as Greenpeace,

A migrant worker strips wires from e-waste in Guiyu, Guangdong Province. Photo Credit: Greenpeace China

the Basel Action Network and Silicon Valley Toxics Coalition have been working aggressively to address the problem "upstream" by demanding that manufacturers of electronic products reduce the amount of hazardous substances that go into their products and take active responsibility for recycling their products once they have reached the end of their useful lives.

It is crucial that manufacturers stop using toxic substances in their products so as to limit toxic exposure for workers and the environment during the dismantling process. Resting the financial burden of taking back end-of-life products on the manufacturers will give them the incentive necessary to design electronic products that are safer and easier to recycle.

Since 2004, Greenpeace has used direct negotiations with companies, non-violent direct actions, research, and other campaign tactics to reach its aim of cleaning up the electronics industry. In China, Greenpeace also launched a consumer campaign directed at creating a demand for greener electronic products and business "take back" within the country. For instance, in 2006, the organization released a purchasing guide designed to help individual consumers seeking to buy greener electronic products. It also helped SACOM, a student-based organization in Hong Kong, to successfully lobby the Chinese University of Hong Kong to adopt a procurement policy where it only purchases from computer companies that offer a free take-back policy.

Greenpeace's efforts combined with public pressure have encouraged companies such as Acer, Dell, Lenovo, LG, Nokia, Samsung, and Sony Ericsson to commit to phase-out a series of toxic substances (e.g., brominated flame retardants and poly-vinyl-

chloride) in their products. Moreover, in 2006, Dell and Lenovo became the first companies to offer a free take-back policy to all their consumers in China—a service that is usually reserved for consumers in developed countries. While these changes cannot eradicate the many problems associated with e-waste, they can at least lead to safer dismantling and recycling in scrap yards such as Guiyu.

FINAL THOUGHTS

The story of Guiyu provides a compelling case for an electronics revolution that promotes the abatement of toxic material use and producer responsibility for product disposal. Such changes must also be combined with strong regulatory pressure that encourages innovation in the industry sector and holds accountable those who violate e-waste trade regulations. Until such changes are made, workers in scrap yards such as in Guiyu will continue to face the risks of e-waste dismantling.

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NOTES

1. A solder is a fusible metal alloy that is melted to join metallic surfaces.

Promoting Pesticide Eco-Alternatives

By Sun Jing

China's large-scale pesticide production and consumption brings with it an inevitable amount of pesticide abuse and misuse. Although the causes of these problems are complicated, many can be attributed to lack of knowledge about the health and environmental risks of pesticides. Raising awareness about these risks is therefore a challenging, but critical step to promote the safe use of pesticides.

Founded in 2002, Pesticide Eco-Alternatives Center (PEAC) based in Kunming (Yunnan Province), is China's first—and still only—environmental NGO focusing exclusively on pesticide problems. The mission of PEAC is to protect human and ecological health threats from farm chemicals by lowering the use of harmful pesticides and promoting alternative forms of pest control. PEAC carries out research and outreach projects that use consumer and farmer participatory approaches. PEAC projects follow a five-pronged strategy:

1) Advancing Pesticide Alternatives and Organic Agriculture

- Promoting classic bio-control practices, such as controlling the green peach aphid in Yuxi, a tobacco growing area in the central part of Yunnan Province, by deploying some of its natural predators.
- Extending or reintroducing indigenous knowledge to control vegetable crop pests through organic farming, such as the traditional practices of intercropping and crop rotation. PEAC has helped to implement some of these alternatives in Yuxi and in Haobaoqing Organic Plantation of Tuanjie town in Yunnan Province.

2) Training and Empowerment of Farmers

PEAC pesticide reduction projects prioritize the active involvement of farming communities. Over the past few years, PEAC has worked with several communities to promote local awareness of pesticide risks. For example, in Chengguan village in Eryuan county (within Dali municipality in Yunnan Province), PEAC has carried out numerous participation-based trainings that have produced some positive changes in pesticide use:

- Whereas farmers in Chengguan village previously used bare hands to mix pesticides, they now wear rubber gloves.
- The percentage of the local people who are using highly toxic pesticides such as methamidophos has been reduced 80 percent. As of 1 January 2007, the Chinese government banned the use of methamidophos in addition to the use of four other highly toxic pesticides—parathion, methyl parathion, monocrotophos and dimecron.
- Groups of village women now regularly and safely clean pesticide containers and packaging materials that were once abandoned to contaminate farmland soil.

Today, farmers in Chenguan village are anxious to reform their farming practices. In order to encourage farmer-led training programs, in October 2006, PEAC helped farming leaders and local officials set up a Community Farmer Training School (CFTS). The school aims to promote sustainable farming, protect human health (especially of women, who do most of the farming) and the environment, and to empower farmers with new working skills and knowledge of relevant laws.

In April 2007, CFTS held a seminar in Chengguan village to discuss the importance of protecting traditional species of rice with local farmers. This seminar also introduced basic knowledge about the potential risks of genetically modified organisms. This was an ambitious initiative for the school, but the seminar effectively organized the participation of numerous journalists, local officials, farmers, agricultural technicians and foreign experts.

Because rural women are primarily responsible for farming and handling pesticides, nearly all PEAC projects include outreach to women as a key component. Photo Credit: PEAC

3) Promoting Consumer Awareness of Pesticide Dangers

To a certain degree, the wide use and abuse of agrochemicals is linked to the demands of the market because consumers prefer large, blemish-free fruits and vegetables. Thus, consumers play an important role in pesticide reduction work. Since 2002, PEAC has held several consumer awareness-raising training programs, which are a mainstay of its activities in Kunming. In order to extend PEAC's training on pesticides, a new website (www.panchina.org) was created in March 2007.

4) Protecting Women's Health

Rural women are particularly vulnerable to the harmful affects of agrochemicals like pesticides, for as men have moved to cities to seek work, the burden of farming increasingly falls to women. Thus, in nearly all PEAC projects, outreach to women is a key component.

5) Developing Appropriate Policy Responses and Advocating Policy Reform

Promoting understanding and good communication between organizations are two key skills for successful policy advocacy. PEAC therefore has become a platform for multi-stakeholder forums that bring government, NGO, researcher, and farmer communities together to discuss pesticide and environment-related issues. Such dialogues are important for expanding thinking on pesticides and pushing policy reform. In June 2006, PEAC held a seminar in Kunming on genetically engineered crops, which included the participation of officials from local and central governments, NGO delegates, stockholders from organic food plantations, scholars and students from local universities, as well as agro-technicians from Xinjiang. Participants sat together with experts from the United States, Malaysia and India to discuss the risks and legislative status of regulating genetically modified organisms.

For more information on PEAC please see: http://www.panchina.org. Sun Jing is deputy director at PEAC and she can be reached at: peac.sj@gmail.com.

COMMENTARY

Complex Tradeoffs: Urban Transport, Land Use, Air Quality, and Health in Chengdu

By Chris P. Nielsen

No resident or visitor encountering China's major cities today fails to experience first-hand the dramatic impacts on urban life and the environment of the recent explosion of Chinese vehicle ownership. These effects can be positive: for many, the convenience of expanded mobility, or for some, the private traveling comfort of a plush seat and air conditioning. Other effects are negative: the clock-watching frustration of traffic gridlock, streets less amenable to pedestrians and bicyclists, or the irritated lungs from inhaled fine particles.

Development of cities and the demand for urban mobility on the scale and pace that China is experiencing pose no mean management challenge to municipal authorities. There are many tradeoffs to judge, some far more complex than they first appear. For example, expanding a road system does not always alleviate congestion, because it also encourages demand. Moreover, planning a city around use of private vehicles marginalizes the needs of the many who cannot afford them; controlling millions of individual emission sources requires policy strategies quite apart from those that target stationary smokestacks; and transport-driven photochemical smog is chemically more complex than primary air pollutants against which China has made progress. Scholarly research on these and related topics, leveraging diverse expertise through collaboration, can build knowledge and capacities to inform urban planning for the future.

THE RESEARCH INITIATIVE

The China Project, an interdisciplinary research program of Harvard University, collaborates with Chinese universities and research institutes to build fundamental scholarship and research capacities relating to atmospheric environment. An ongoing initiative of the China Project, coordinated with Tsinghua University, focuses on the city of Chengdu to explore confluences of urban transportation, land use planning, vehicle emissions, and effects of mobile-source air pollution on human health and the economy.

The Chengdu initiative seeks not to answer policy questions posed by government, rather to explore innovations in independent, basic research—ideally applicable to cities in general—that in turn may strengthen capacities to inform policy deliberation. A number of separate but linked subsidiary studies are underway covering original data collection, development and application of models, and analyses. Individual studies have timelines, but the initiative as a whole is open-ended and is evolving as research interests of participants dictate. Findings are submitted to peer-reviewed academic journals, with a collection in an edited volume planned. Results are also presented in seminars, workshops, and conferences. (*Editor's Note: Notices of past and future seminars at Harvard on Chengdu work are listed at chinaproject.harvard.edu*).

The Chengdu initiative was motivated in part by research on the transport sector in the China Project's recently published national assessment: *Clearing the Air: The Health and Economic Damages of Air Pollution in China* (Ho & Nielsen, 2007). This study identified mobile-source air pollutants, and associated population health risks, as an essential area for new research. The Chengdu initiative builds on the book's exposure assessment methods. It also adopts its modular structure, in which teams of scholars pursue independent research interests, but under an umbrella of cross-disciplinary review that fosters confluence and sparks new research ideas.

Organized chaos: Segregation of transport modes at a Chengdu intersection. Photo Credit: Chris Nielsen

All researchers tackling topics on China's environment swiftly run up against a hard constraint: limits in the quantity, accuracy, and availability of primary data. Official data are sometimes accessible, but rarely with detail on how they were collected and thus how research might control for their inherent biases. This is not a criticism, as official data are gathered to meet the needs of management objectives, not scholarly ones; however, their utility to basic research depends on such information. The Chengdu initiative has therefore invested heavily in fieldwork, led by Chinese participants, to collect original data.

BUILDING RESEARCH TOOLS: DATA COLLECTION AND ANALYTICAL METHODS

Household Survey

Chief among data collection efforts was a comprehensive survey of 1,001 households in the summer and fall of 2005, administered by the Research Center for Contemporary China of Peking University led by Shen Mingming. Conducted in two waves of interviews, the survey was designed to serve the needs of the program's researchers across many fields. It included sections on travel behavior, mode choice, daily trip diaries, land use and proximity to amenities, socioeconomic conditions, popular perceptions of transport, environment, the value of health, and more.

For a survey to represent a target population, its sample must be unbiased. Almost all probability-sampled household surveys in China draw from official lists such as the oft-violated household registration (*hukou*) system. A central distinction of the Chengdu survey was a painstaking sampling approach to include the large population of migrants who remain off urban *hukou* rolls. China's 2000 census estimated this pool of migrants nationally at 144 million, including a large "floating population" that moves between urban and rural areas following economic opportunities. Migrants are typically poorer, less educated, and more dependent on non-motorized and public forms of transportation. Omitting them from surveys systematically biases findings against their interests, perpetuating a view that migrants do not "officially" exist, or at least do not merit equal consideration, for the purposes of urban, transport, and environmental planning. Aside from obvious implications for social inequity, this may lead to policies mismatched to actual pressures on the ground.

A sampling protocol designed to address undercounting of urban migrants in China—and applicable to any context with problematic population counts—is described in Landry & Shen (2005), and was employed in the Chengdu household survey. In this spatially based sampling method, a jurisdiction is precisely gridded and surveyed by teams using satellite-based Global Positioning System (GPS) receivers. As long as *all* households and residents in spatial sampling units are identified and enumerated, the likelihood of selection can be deduced. The result is a truer equal-probability sample. (Space does not allow making the statistical case for this protocol, for more information see Landry & Shen, 2005).

Travel Demand

Urban governments like Chengdu's need integrated planning that considers land use, transportation, and environment in concert, but generally lack the detailed and costly land use and travel behavior data required to forecast travel demand. A technical team led by Joan L. Walker of the Center for Transportation Studies at Boston University (BU), Sumeeta Srinivasan of Harvard, and Li Jieping of BU and Harvard is seeking to improve travel demand modeling under such constraints. The team has used commuting data from the Chengdu survey to test the development of mode-choice travel demand models where level-of-service data—i.e., times and costs—are poor (Walker et al., 2007).[1] The results spotlight that models failing to control for measurement error will underestimate travelers'

values of time, which in turn will lead to incorrect travel demand forecasts.

Vehicle Activities and Emissions

To estimate emissions from the transport system for modeling air quality and human exposure, a field study of vehicle activities is led by He Kebin of Tsinghua. It combines existing datasets for Chengdu with new data collected according to the International Vehicle Emission Model (IVE) that his team previously applied in Tianjin and Beijing (Liu et al., 2005). IVE is a protocol of intensive field efforts that include estimating the on-road vehicle distribution by: (1) counting vehicles videotaped at carefully sampled streets, (2) surveying vehicle and emission technologies in sampled parking areas, and (3) characterizing driving cycles and start patterns using GPS receivers and voltage sensors mounted onboard sampled vehicles.

> **"Planning a city around private vehicles marginalizes the needs of the many who cannot afford them.**

Air Quality and Human Exposures

If one wants to understand total population risk from mobile-source air pollution, a central question is how health effects of concentrated exposures to primary pollutants on and near streets compare to those of less concentrated primary and secondary pollutants dispersed over a region. This is a function of many determinants, including emissions, air transport and chemistry, population distribution, and time-activities, notably where and when people are outdoors versus indoors.

Wang Shuxiao of Tsinghua has been modeling the fate of vehicle emissions in Chengdu, including air dispersion and human exposures, building on the "intake fraction" method applied to transport sources in *Clearing the Air* (Wang et al., 2007).[2] Wang led field efforts to observe traffic and measure nitrogen oxides and particulates at three road segments in Chengdu, and to test them against street canyon simulations. She also has used a preliminary emission inventory and simple dispersion model to simulate urban-scale concentrations. With time-activities derived in part from the household survey's trip diaries, Wang is calculating intake fractions of mobile-source pollutants in Chengdu, a key input to analyses of the health benefits of transportation options.

Health Valuation

Estimates of the Willingness-to-Pay (WTP) to reduce health risk—on which there are very few published, peer-reviewed studies for China—are essential inputs to analyses of the costs and benefits of pollution control, a form of policy analysis preferred by many decision-makers. The Chengdu household survey was initially designed for a "contingent valuation" study of the economic values of air-pollution-related health risks by a team including James K. Hammitt of the Harvard School of Public Health and Guo Xiaoqi of the China Project and Ohio State University (Guo, 2006; Guo et al., 2007). In contingent valuation, a survey asks respondents to directly value a good or service in a hypothetical market. The health risks evaluated here were cases of asthma and premature mortality. This study also explores respondents' motivations by testing whether WTP depends on how the health risk is reduced: through the private market (paying directly for a treatment) or through a public health policy, paid by a tax.

APPLYING RESEARCH TOOLS: ISSUES, OPTIONS, AND COMPARISONS

Costs and Benefits of Transit Options

Most of the outputs of research described above—especially emission estimates, intake fractions, and health valuations—can be brought together as inputs to evaluation of costs and benefits of possible interventions in Chengdu's transportation system. The goal of the Chengdu initiative remains research innovation more than direct policy applications. In the next phase of cost-benefit analysis, all the researchers discussed above, along with Peter Rogers from Harvard and the author, have begun to assess potential new policies and programs that influence travel behavior in ways that lessen harmful air pollution. Analyzing such policies to see if they are applicable to China is complex and demands more collaboration across research fields.

For example, the research team is starting with cost-benefit analyses of two comparatively simple

transit system interventions. The first focuses on bus technology retrofits such as diesel particle filters, following similar analyses applying intake fractions in Mexico City (Stevens et al., 2005) and Boston (Greco, 2006). The main benefit is reduction of health risk by reducing vehicle emissions, also translated to economic values. This is relatively easy to estimate, because the intervention engenders no change in travel behavior. A second cost-benefit analysis explores Bus Rapid Transit (BRT) on specific routes in Chengdu. BRT will displace traditional transit buses, if not other modes, and may influence travel demand of commuters and vehicle activities on target roads. These changes may bring benefits from saved travel time and cost, along with reduced emissions and health risks.

Transportation, Land Use, Income, and Gender

Sumeeta Srinivasan of Harvard is investigating the relationships of land use to travel behavior, including differentiation by income and gender, through measures of accessibility (Srinivasan, 2007a,b). Accessibility is a central but elusive quality capturing the ability of an individual to conduct activities in a given environment. It recognizes that the final objective of planning a land use-transportation system is not *transportation* or even *mobility* per se—with supply-side bias—but *accessibility* of amenities needed for daily life. Planners must consider, moreover, that place-based accessibility varies widely for different segments of the population. For example, the Chengdu survey confirms that women and low- and middle-income households are more dependent on public transit and walking. This emphasizes that public transit routes and pedestrian facilities can and should be planned accordingly, to target the needs of those who depend on them most in their daily lives.

International Comparisons

Srinivasan (2007b) explores the roles of income and gender in part through comparison of Chengdu and Chennai, India. She and P. Christopher Zegras of M.I.T. also have used the household survey to contrast mobility and accessibility across income groups in Chengdu and Santiago, Chile, two cities with roughly equivalent purchasing-power-adjusted GDP per capita (Zegras & Srinivasan, 2007). Among other lines of inquiry, they spotlight how cultures, histories, and economic systems are powerful determinants of travel behavior and accessibility. Notably, for all the attention to China's swift motorization, this study illustrates how comparatively dependent Chengdu citizens remain on walking and bicycling, and how little mode share is served by cars, taxis, and even buses. Along with the many comparisons, the authors explore how accessibility might be measured in the two cities.

VALUE OF THE STUDY BEYOND CHENGDU

City leaders in China, as around the world, are realizing the inescapable interdependency of urban transport, land use, and air quality. The challenge of integrated urban planning is in part political, with entrenched, even rival, bureaucracies organized as if these are separable concerns. No one should overlook, however, that the challenge is, perhaps more fundamentally, a complex intellectual one. The tradeoffs among urban transport, land use, and air quality, not to mention other public needs, are not easily understood or even described, let alone resolved. Wholesale solutions are very unlikely. For any city, progress will be piecemeal, but accelerated if informed by objective data, analytical capacities, and a body of relevant knowledge developed over time. Independent, collaborative scholarship can play a valuable role, leveraging perspectives across disciplines, and past experience across national boundaries, in ways more politicized, government-based processes cannot.

The Chengdu program grew from seed funding of the V. Kann Rasmussen Foundation. Much current research is supported by the Volvo Research and Educational Foundations. Elements of the household survey were funded by the Harvard Real Estate Academic Initiative and the Harvard Asia Center, the latter also supporting a research and policy workshop held in Chengdu with local scholars and municipal leaders. The many research participants in the United States and China thank all funders for their generous and flexible support.

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NOTES

1. For the technically interested, the team's approach is to treat level of service as a latent, unobserved variable, and use measurement equations to represent it in a hybrid choice model.

2. Intake fraction is a research tool for approximating the proportion of total emissions from a given source that ultimately reaches human lungs.

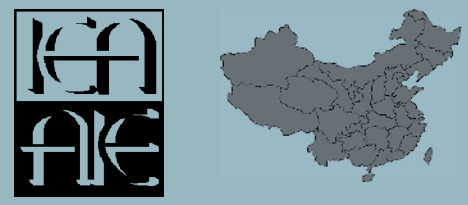
FEATURE BOX

Highlights of International Energy Agency-China Activities

By Jonathan Sinton

The oil crisis of 1973-74 shocked the nations of the industrial world into taking action to ensure that they would never again be so vulnerable to a major disruption in oil supplies. The result was the creation in 1974 of the International Energy Agency (IEA), a cooperative group of industrialized member countries (now numbering 26), committed to responding swiftly and effectively to future oil emergencies and to reducing their dependence on oil. To attain these objectives, member countries agreed to establish emergency oil stocks, reduce consumption, and—if necessary—share supplies. They also committed to increase the efficiency of their use of energy, conserve this valuable resource, and diversify their energy supplies through development of alternatives to oil.

Energy markets have changed significantly since 1974 and with them, the scope of IEA work, which now focuses on broader energy issues beyond oil crisis management, including climate change policies, market reform, and energy technology collaboration. As energy demand and supply become increasingly driven by non-OECD countries, close collaboration with key consuming countries like China and India becomes a priority. The IEA has been studying energy-related developments and drawing policy lessons from over 30 years of global experience. One of the IEA's key departments, the Office of Global Energy Dialogue, was established in 1993 to better understand the energy situation of key transition and emerging economies outside IEA membership, and to develop policy dialogue and collaborative programs with them. The IEA is strengthening ties with these countries, and this outreach forms an important part of the IEA focus on promoting global energy security, environmental protection, and economic development.



IEA-CHINA ACTIVITIES

Since the early 1990s, China and the IEA have had frequent high-level meetings, regular exchanges of visitors and statistical information, joint workshops and training sessions, and collaboration on in-depth analysis projects. In every major IEA study, special attention is paid to China; the IEA's yearly *World Energy Outlook* has had a chapter on China since 1996, and the 2007 issue focused on China and India. Moreover, the IEA seeks to deepen China's participation in the work of the IEA by extending invitations to Chinese officials to observe selected IEA governing board and committee meetings. Following are some highlights:

Formal Agreements

- In October 1996, the IEA and the National Development and Reform Commission (NDRC) signed a *Memorandum of Policy Understanding in the Field of Energy*.
- In August 2001, the IEA and the Ministry of Science and Technology signed a *Framework for Energy Technology Co-operation*.

Energy Statistics

- Since receiving statisticians from China's National Bureau of Statistics (NBS) in 1996 and

"As energy demand and supply become increasingly driven by non-OECD countries, close collaboration with key consuming countries like China and India becomes a priority.

2000 for training, IEA now has a regular channel of communication and exchange with NBS.
- China has joined as a participant in the multinational Joint Oil Data Initiative (www.jodidata.org).
- The IEA trained Chinese oil statisticians in Paris in October 2006 to assist in establishing China's emergency oil data system and to improve oil statistics.
- The IEA is currently providing training on best-practice energy statistical methods to national, provincial, and municipal energy statisticians in 2007, with support from the United Kingdom.

Coal

- China's largest coal producer, Shenhua, joined the IEA's Coal Industry Advisory Board (CIAB) in 2007. CIAB is composed of CEOs from 40 of the world's largest coal companies, and provides the industry's perspective on key issues to the IEA and its member countries (www.iea.org/ciab).
- In cooperation with NDRC, the IEA, supported by the UK, has commenced projects to analyze China's strategy for cleaner coal and the place of international cooperation in it, and options for refurbishing or closing older coal-fired power plants.
- The IEA and CIAB will hold a conference on clean coal technology and policy in Beijing in May 2008.

Oil Markets and Emergency Preparedness

- Chinese experts participated in 2004's Emergency Response Exercise (ERE) 3 in Paris, and have been invited to join ERE 4 in 2007-2008.
- In February 2006, colleagues in China completed translation into Chinese of IEA's publication *Oil Supply Security*, as well as supplied information for the 2007 update of the publication.
- A joint workshop on oil security in was held with NDRC in Beijing in October 2006.

Natural Gas

- In 1999, IEA and Chinese partners began researching natural gas issues in China, which led to the December 2002 publication of *Developing China's Natural Gas Markets.*
- IEA technical assistance and outreach projects are underway on both landfill methane and coalmine methane.

Electricity

- The IEA worked with experts in China to prepare *China's Power Sector Reforms: Where to Next,* a study released July 2006.
- China's power company State Grid has asked IEA for technical assistance in planning for regulatory evolution in the power sector.

Renewables

- Chinese delegates have attended meetings of the IEA Renewable Energy Working Party.
- A detailed assessment of China's renewable energy markets and policies will be a major input to the global assessment of renewables that the IEA is currently preparing.

Energy Efficiency

- In 2006 and 2007, Chinese delegates have participated in workshops at the IEA on energy indicators and industrial energy efficiency, as part of the IEA's support for China's ambitious plans to improve energy efficiency, and to carry out the G8 Gleneagles Plan of Action.[1]
- The IEA co-organized with the World Business Council for Sustainable Development a major conference on building energy efficiency in Beijing in March 2007.
- IEA-China cooperation on transport energy efficiency now includes fuel economy standards for heavy-duty vehicles and efficient tires.

Energy Technologies

- China is a contracting party in three energy-technology R&D cooperation programs—hydropower, fusion materials, and multiphase flow. China is also a sponsor in the IEA Clean Coal Centre.
- Under the G8 Gleneagles Plan of Action, IEA carried out an energy technologies workshop in November 2007 in Beijing.
- With support from the UK and in collaboration with the World Bank on G8 activities, the IEA is supporting work on energy technology indicators and scenarios in China.

Climate Change

- In accordance with the G8 Gleneagles Plan of Action, the IEA and China are discussing new collaborative activities to track greenhouse gas emissions and develop strategies to cope with the challenge of climate change.
- The 2008 edition of the *World Energy Outlook* will focus on climate change, including analysis of the potential role of China and other developing countries in ameliorating energy-related greenhouse gas emissions.

Publications mentioned above are available at www.iea.org. For other questions please contact Jonathan E. Sinton, at +33 (0)1 40 57 65 05 or Jonathan.Sinton@iea.org.

NOTES

1. Under the G8 Gleneagles Plan of Action, the IEA is working with partners around the globe to focus on climate change, clean energy and sustainable development. The IEA's G8 Gleneagles Programme is promoting energy-sector innovation, better practice and use of enhanced technology.

COMMENTARY

A Case Study in Indoor Air Pollution and Lung Cancer in Xuan Wei, China

By H. Dean Hosgood, III

Globally, lung cancer is estimated to account for 1.4 million cancer cases and 1.2 million cancer deaths per year.[1] While smoking is the primary risk factor of lung cancer, domestic fuel combustion from cooking and heating is also associated with the disease.[2] About half of the world's population, approximately 3 billion people, almost all living in developing countries such as China, are exposed daily to high levels of domestic fuel combustion.[3]

XUAN WEI COUNTY: HIGHEST LUNG CANCER RATES IN CHINA

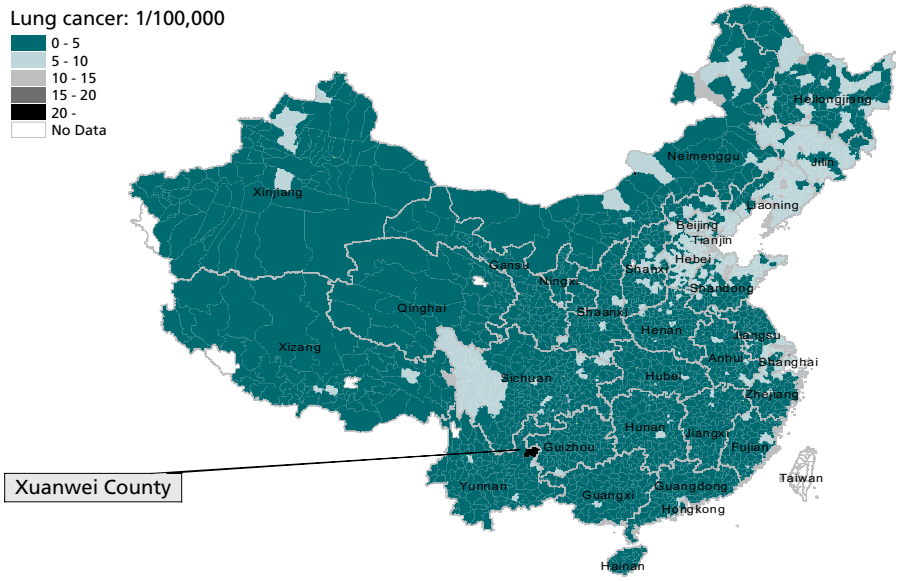
Xuan Wei is a coal-rich semi-mountainous county in eastern Yunnan Province. The population of Xuan Wei has especially high in-home coal smoke exposure due to the widespread use of smoky (bituminous) coal for heating and cooking. Xuan Wei has the highest prevalence of lung cancer in China and greater than 90 percent of these cases are due to coal smoke exposure.[4] (See Figure 1). In Xuan Wei, nearly all women and few men cook, while most men and nearly no women smoke tobacco.[5] These characteristics make the location ideal to study the impacts of coal smoke in women because it eliminates the overlapping influence of tobacco smoking that confuses analyses in other populations. Further, 90 percent of Xuan Wei's residents are farmers and have minimal industrial and automotive air pollution exposure.[6]

Early studies in Xuan Wei provided evidence suggesting that risk of lung cancer attributed to coal exposure might be driven by exposures to polycyclic aromatic hydrocarbons (PAHs). Exposure assessments of the indoor air pollution generated from the burning of smoky coal in fire pits found elevated levels of airborne benzo(a)pyrene, a strong indicator of the presence of PAHs.[6,7] Further studies on biological samples supported this hypothesis. For example, mutations in the p53 gene in tumor samples from nonsmoking women in Xuan Wei were consistent with those of PAHs and different from those of lung cancer tumors from smokers.[8] Also, exposure to smoky coal has been associated with increased levels of PAHs bound directly to human DNA, or PAH–DNA adducts, in placentas and cord white blood cells in this population.[9]

IMPACT OF STOVE IMPROVEMENTS IN XUAN WEI

Beyond exploring the carcinogenic agents in the smoke, Xuan Wei has offered an exceptional opportunity to study the impact stove improvements have on human health. The Xuan Wei Cohort Study, which was initiated by the U.S. Environmental Protection Agency and the Chinese Academy of Preventative Medicine in 1992, is comprised of 42,422 consenting farmers who were born between 1917 and 1951. The study area consisted of Xuan Wei's three central communes, covering 175 square miles, selected because these communes have had the highest lung cancer mortality rates in Xuan Wei. Subjects were retrospectively followed from 1976 to 1992. To date, this is the only study in the world to have evaluated the long-term health benefits of combustion exposure reduction in subjects who underwent stove improvement. The stove improvements were part of the China National Improved Stove Program, which installed 129 million new stoves in rural homes between 1982 and 1992. Study subjects underwent stove improvements from fire pits to stoves with chimneys, stoves without chimneys,

FIGURE 1. County Specific Female Lung Cancer Mortality Rates (per 100,000) in China, 1973 – 1975



Source: Mumford JL, He XZ, Chapman RS, Cao SR, Harris DB, Li XM et al. (1987).

or portable stoves. Significant reductions in lung cancer incidence and chronic obstructive pulmonary disease (COPD) in both men and women using smoky coal were associated with improvement from fire pits to stoves with chimneys.[5,10] The stove intervention also significantly decreased the indoor airborne concentrations of particulate matter (PM10) and benzo(a)pyrene.[5]

GENETIC SUSCEPTIBILITY STUDIES

Recently, findings from a pilot molecular epidemiology case-control study in Xuan Wei have provided evidence of genetic susceptibility to lung cancer in populations with smoky coal exposure. This study was primarily undertaken by the U.S. National Cancer Institute, in collaboration with the Chinese Center for Disease Control and State Environmental Protection Administration. This population-based case-control study was carried out between 1995 and 1996 and included 122 lung cancer cases and 122 controls individually matched based on age and gender. Subjects with exposure to smoky coal combustion and genetic variation in the DNA repair pathway genes,[11] the immunoregulatory genes,[12] the base excision repair genes,[13] and the one-carbon metabolism pathway genes[14] have been found to be genetically susceptible to lung cancer in this population. Furthermore, subjects with variations in key genes involved in the metabolism (activation and detoxification) of PAHs were also at an elevated risk for lung cancer.[15,16] While this pilot study was one of the first to evaluate these genotypes and lung cancer susceptibility in such a population, new studies in other populations with similar exposures have replicated some of the findings.[17]

POLICY IMPLICATIONS

Currently, ongoing studies by the U.S. National Cancer Institute, in collaboration with the Chinese Center for Disease Control and State Environmental Protection Administration, are underway to expand on the findings from the cohort study and the molecular epidemiology case-control study. An extended follow-up of the Xuan Wei Cohort Study will potentially allow researchers to evaluate stove improvement effects on other diseases and in subjects utilizing other fuel types and stove types. This research will hopefully assist Chinese policymakers

Photo showing exposure of Xuan Wei farmers to indoor air pollution. Photo Credit: Dr. Qing Lan

in determining the most cost-effective manner to reduce indoor air pollution and increase both short- and long-term health benefits.

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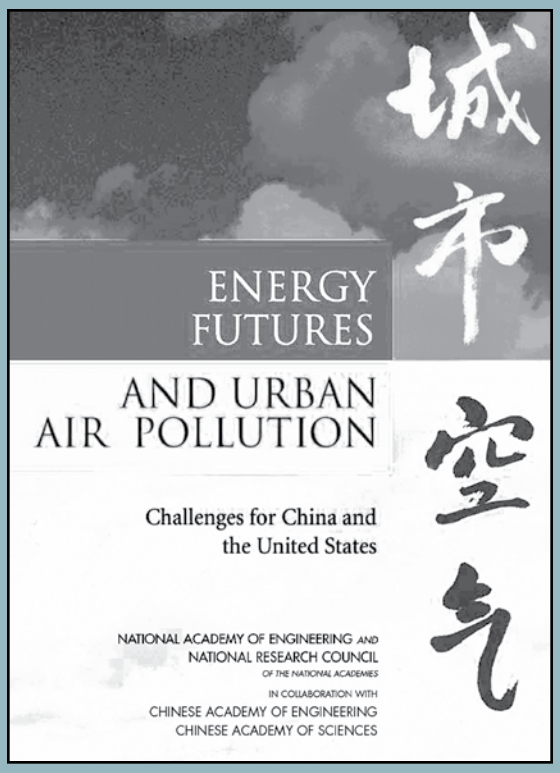
FEATURE BOX

Energy Futures and Urban Air Pollution:

Challenges for China and the United States (2007)

The United States and China are the number one and two energy consumers in the world, with China being the largest emitter of sulfur dioxide (SO_2) and both countries leading the world in carbon dioxide emissions (CO_2) due to their extensive use of fossil fuels. To examine the energy use and urban air pollution challenges faced by these two countries, the U.S. National Academies, in cooperation with the Chinese Academy of Engineering (CAE) and the Chinese Academy of Sciences (CAS), jointly researched and coauthored the book *Energy Futures and Urban Air Pollution: Challenges for China and the United States.*

This comparative study identifies lessons learned from case studies of four cities (Pittsburgh and Los Angeles in the United States and Huainan and Dalian in China); addresses key technological and institutional challenges and opportunities; and highlights areas for continued cooperation between the United States and China on energy and air quality issues. The report is geared towards policymakers at all levels of government as they seek to balance urban energy consumption with air quality management. It is the hope that the report is of value to policy communities not only in China and the United States, but also other countries worldwide.



FEATURE BOX

Partnership for Clean Indoor Air in Guizhou Province: Promoting Environmental Health in Rural China

By Jennifer L. Turner

Among the 57 percent of China's population living in rural areas, indoor air pollution affects the lives of over 700 million people, many of whom are women and children living in the poor province of Guizhou, where people cook and warm their homes with biomass and coal they mine themselves. The China Environment Forum hosted two speakers, Dr. Jin Yinglong and Mr. Tang Ning, from the Chinese Center for Disease Control's (CDC's) Institute for Environmental Health and Related Product Safety (IEHS) on 13 June 2006 to discuss the status of their environmental health projects in Guizhou Province. Throughout the world, indoor air pollution (IAP) has been difficult to address due to its multi-disciplinary nature, which requires nongovernmental organizations and policymakers to consider energy, deforestation, gender issues, health, and economic development as they seek solutions.

Indoor Air Pollution and Environmental Health

Most of China's rural population cooks indoors with highly inefficient stoves. This creates a situation in which the combustion of coal and biomass release hundreds of pollutants at levels several times higher than general health guidelines. Notably, in Guizhou Province, rural residents burn coal briquettes that contain a high level of naturally occurring arsenic and fluoride.

Some of the health impacts linked with indoor air pollution include dental and skeletal fluorosis, respiratory diseases, and acute respiratory infections. It is therefore not surprising that one of the leading causes of death among rural children in China is pneumonia. In Guizhou alone, over the past few years there were 10 million dental fluorosis patients and 640,000 people suffer from skeletal fluorosis. Besides inhalation of the smoke, one of the main causes behind these grim statistics is the link between smoke and food preparation methods. In rural Guizhou residents dry corn, chili peppers, and meat above their coal-burning stoves; thus, people end up digesting high amounts of fluoride and arsenic. In their assessment of counties in Guizhou, the IHES researchers found that along with food preparation methods, the use of inefficient stoves and chimneys (or lack of chimneys) were all contributing to the severe indoor air pollution.

The Institute for Environmental Health & Related Product Safety

IEHS of the Chinese CDC is promoting efficient coal and biomass usage throughout rural Guizhou and Gansu provinces and Inner Mongolia with the goal of creating multi-stakeholder programs promoting clean cooking stoves that can be replicated around China. Established in May 2002, the IEHS is an incorporation of the former Institute of Environmental Health and Engineering, Institute of Environmental Health Monitoring, and Chinese Academy of Preventive Medicine. As China's national professional institution for environmental health and product safety, it provides scientific research and technical support to guide policy, regulations, and strategies within the Ministry of Health and provincial CDCs. IEHS also holds numerous national and international seminars and training workshops on environmental health matters.

The Partnership for Clean Indoor Air Pilot Project in Guizhou

To address severe indoor air health problems in China, IEHS has been working with the U.S. Environmental Protection Agency on a pilot project

that has: (1) distributed energy efficient stoves, (2) incorporated health and environmental awareness into the local school curriculums, (3) promoted local clean cook stove production/distribution businesses, (4) trained locals in stove maintenance methods, and (5) tested and marketed a number of other clean household energy technologies such as biogas digester systems and solar cookers.

The project began by targeting 50,000 households in seven counties in Guizhou for dissemination of improved stoves and chimneys. The IEHS researchers first established a local team to help in the design, distribution, and follow-up education of the clean cook stove program. The team included village, township, and country government officials, as well as local representatives of the community, the Chinese Women's Federation, and the energy, finance, and agriculture sectors.

In an attempt to guarantee community commitment and to encourage a sense of personal investment, rural residents were encouraged to purchase the biomass stoves through a soft-subsidy strategy. Currently, residents in the targeted rural communities put forward 30 percent of the cost of the stoves, with the rest being subsidized by IEHS; however, this will rise to 50 percent in the future.

Along with the dissemination of cook stoves, IEHS and the local team set up health education activities at township and village levels. One of the more interesting methods for environmental health information dissemination was to target young children, in hopes they would then pass on their newfound knowledge to their parents. Other methods included passing out leaflets, community meetings, and even artistic performances to underscore the linkage between poor cook stoves and health problems. Education efforts led many villagers to write and sign a pact laying out rules on how the stoves would be used correctly in the community. The education curriculum also targeted behavioral changes by suggesting different food preparation methods, such as sun-drying rather than smoke-drying foodstuffs, storing items in bags instead of around coal stoves, and washing food more carefully before eating.

Although the IEHS staff recognizes there are still numerous environmental health threats in rural China—such as excessive usage of pesticides and fertilizers that are contaminating ground water systems—the Guizhou IAP project represents a promising model for the national government to engage local governments and citizens to become environmentally conscious and to become proactive about seeking solutions to local environmental health problems. Such collaboration among government agencies and communities is still rare in China, but necessary to help promote stronger implementation of environmental protection policies and programs.

For more information on IEHS contact Ning Tang at ningtanglcp@126.com. Queries on the Partnership for Clean Indoor Air should be directed to John Mitchell at Michell.John@epa.gov and Brenda Doroski at Doroski.Brenda@epa.gov.