Project Completion Report

Scoping Water and Energy Pollution Nexus in Urumqi and Qingdao for Preparing PRC's Ministry of Environmental Protection Co-Control Program

Supported by:

RETA 6498: Knowledge and Innovation Support for ADB's Water Financing Program – Pilot and Demonstration Activity for the People's Republic of China

Report submitted to:

Environment, Natural Resources and Agriculture Division
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Asian Development Bank
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Circle of Blue, a project of the Pacific Institute, March 2013

Abbreviations and Acronyms

ADB	Asian Development Bank
CEF	China Environment Forum
CoB	Circle of Blue
CRAES	Chinese Research Academy for Environmental Science
EPA	United States Environmental Protection Agency
GHG	Greenhouse gases
MEP	Ministry of Environmental Protection
MOHURD	Ministry of Housing and Urban and Rural Development
NGO	Non-Governmental Organization
PDA	Pilot and Demonstration Activity
PI	Pacific Institute
PRC	People's Republic of China
PRCEE	Policy Research Center for Environment and Economy
RETA	Regional Technical Assistance (for knowledge and innovation support)
WWC	Woodrow Wilson International Center for Scholars

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I. Project Background and Context

A. Issues and Challenges (Why The Need For The PDA)

According to Chinese authorities and government reports, PRC's demand for energy, particularly for coal, is outpacing its freshwater supply. That, in turn, threatens the productivity of PRC's farm sector and the economic stability of its fast-growing northern and western cities.

Researchers at PRC's Ministry of Environmental Protection's Policy Research Center for Environment and Economy (PRCEE), Beijing Normal University (BNU), and Qingdao University of Science and Technology (QUST) are developing research and industrial management practices designed to reduce PRC's dependence on coal. They are developing a methodology of "co-control" to identify and implement cost-effective control measures that reduce emissions of greenhouse gases and conventional air pollutants in a way that maximizes co-benefits.

The PDA White Paper provides a detailed assessment of how the cities of Urumqi and Qingdao are grappling with the water and energy challenges, and makes the case that the co-control pilots conducted by the Ministry of Environmental Protection (MEP) in Urumqi can be applied in Qingdao, and duplicated in other cities.

B What the Project is About (rationale, objectives, expected outcomes)

The overall goal of the PDA are to produce a detailed assessment of how the cities of Urumqi and Qingdao are grappling with the water and energy challenges and whether the co-control pilots conducted by the Policy Research Center for Environment and Economics (PRCEE) under China's Ministry of Environmental Protection (MEP) can be scaled and duplicated in other cities.

The specific objectives are to:

(i) Collect relevant information in coordination with PRCEE researchers and co-author a research report that will produce greater understanding about the water-energy confrontations in PRC, and will document potential measures to address them in two geographically, economically, and ecologically distinct cities: one city in PRC's dry and economically challenged northwest and one booming city on PRC's wealthy and relatively more water-rich north-eastern coast;

(ii) Provide input for PRCEE to design an integrated pollution co-control program for MEP's 13th Five Year Plan. This scoping work is an important step to develop the co-control program; and,

(iii) Help PRCEE and MEP lay out a research agenda to expand MEP's co-control approach to incorporate water.

C. The Project Area and Its Relevance

Aside from being representatives of the two economic—and in some ways ecological—extremes of PRC's cities, Qingdao and Urumqi were chosen because both are targets of a new MEP Co-Control Pilot Study. MEP's PRCEE, which is leading these research pilots, plans to integrate water into this analysis, for recent studies in the United States have demonstrated that improvements in urban water conservation and water pollution control can produce great reductions in greenhouse gas emissions.

The examination of the water-energy nexus in cities involved on-the-ground field research and data gathering. The interviews and data collection allowed for the compilation of expert opinion and up-to-date information on the confrontation between rising energy, increasing pollution, and diminishing freshwater resources in two of PRC's cities. This included consideration of such factors as water use efficiency and water loss (i.e., non-revenue water), extraction and aquifer recharge rates, trade-offs between use of water for energy production and other uses, including agriculture.

The research highlighted new innovation at the city level in PRC that offers models for international engagement to help cities worldwide decrease their energy and water footprint

II. Methods Applied and Main Output

A. Methods Applied and Processes Followed

A three-person team of researchers from Circle of Blue (COB) collaborated with PRCEE researchers. A total of 19 days was spent by COB interviewing experts and collecting data in Qingdao and Urumqi. The COB team spent four days in Qingdao in June 2012, and six more days in September 2012. The COB spent 9 days in Urumqi in September 2012. PRCEE conducted additional meetings for a week in January, during which time the staff made presentations of their co-control work to provincial and municipal environmental and planning agencies.

COB prepared a comprehensive list of questions (see appendix 1 in the white paper for the questionnaire) to apply to its data gathering in Urumqi and Qingdao, and to guide its interviews. The comprehensive list proved valuable in amassing the facts that support this report's findings.

COB conducted formal interviews with 26 individuals representing 20 research organizations, municipal and national government agencies, utilities, and universities (see appendix 2 in the white paper for the list of institutions). Data were collected on energy consumption, water supply, and planned tradeoffs between use of water for energy production and other uses, including agriculture.

In conducting its field research in Urumqi and Qingdao, COB focused on the value of incorporating the water sector as a point of research and reference for PRCEE's co-control methodology to limit emissions of sulfur, nitrogen, particulates and carbon. Methane was not included in PRCEE co-control research. The second primary focus of this research project was the coal sector, and the steps Urumqi and Qingdao may be taking to reduce their consumption of coal, which also has the effect of reducing demand for water.

A third objective of this study was to understand the influence that water transport, water treatment, water recycling and other energy-intensive uses of water plays in coal consumption and air pollution in Urumqi and Qingdao.

The final phase consisted of the preparation of a power point that PRCEE will use to deliver in the coming month to city and central MEP officials.

1. Field Research

1.1. Hold editorial planning workshop
1.2. Arrange interviews and visits
1.3. Conduct field research, data collection in Urumqi and Qingdao with MEP and PRCEE staff
1.4. Analyze information and data, and share initial findings with MEP, PRCEE, and ADB
1.5. Write and edit report

Final Status:
All targets were met for Field Research objectives, even though the leadership changeover limited the PRCEE to only send one staff member to Urumqi to work with the COB team. Another member met with COB in Beijing to discuss PRCEE data and background of co-control work. The PRCEE sent a larger team to do a final trip to Urumqi in January and was able to provide COB and CEF with some data we were lacking.

2. Scoping Study

2.1. Gather information on models and methodology used in the U.S. EPA and various U.S. research centers that incorporate water into energy and/or air pollution studies.
2.2. Organize policy dialogues with MEP researchers and senior officials to understand their policy and information needs for co-control program in the 13th Five-year Plan
2.3. Provide inputs to MEP and PRCEE on the design of an integrated pollution co-control program
2.4. Complete draft design in cooperation with PRCEE

Final Status:
Scoping Study objectives were met and the PRCEE team was very responsive in helping us set up meeting and in giving us input on the white paper design. We were however unable to secure water recharge data, but have informed our PRCEE partners that as they move forward developing co-control analyses incorporating water that they will need to include that data.

B. Main Outputs / Presentations

COB to prepare a PowerPoint presentation for policy workshop with MEP and PRCEE to deliver the final results.

Final Status:
White paper study, and accompanying power point presentation, are completed. Dr. Hu Tao and his team reviewed the white paper and power point in the various near final and final drafts. The PRCEE team is planning to discuss this report at a meeting in Urumqi in mid-March 2013 and later use this report and PowerPoint at future talks in Beijing, Qingdao and Urumqi in

order to raise the issue of integrating water into co-control analyses and regulation. The white paper is targeted and informative for all stakeholders. With ADB approval COB and CEF will be disseminating this paper broadly through its water and energy networks globally.

III. Project Outcomes and Lessons Learned

A. What are the Outcomes So Far

An air pollution co-control policy dialogue between PRCEE team and the Xinjiang Environmental Protection Department Director-General will be held on March 17, 2013 in Urumqi. The dialogue will include a discussion of this ADB-supported PDA in order to raise the issue of water being incorporated into co-control pilots. PRCEE researchers are planning to conduct further research for implementing a co-control plan in Urumqi and expand the pilot work to Qingdao and Chengdu. The China Environment Forum (CEF) is introducing various water-energy modelers from Sandia and Brookhaven National Laboratories to PRCEE researchers. The meetings, scheduled to occur late May 2013, will promote the sharing of models that have been developed in the United States to understand water-energy nexus dynamics and trends. Brookhaven National Laboratories is working in China on broader Eco-City pilot projects to improve urban sustainability, which open up future opportunities for direct exchange.

Circle of Blue (COB) and the CEF are planning to utilize insights from conducting these water-energy-air pollution co-control analyses of Chinese cities to create a broader project to examine other cities in China, India, and the United States and create dialogues on municipal innovations to address water-energy-air quality choke points.

As this study shows, a portion of PRC's new demand for power is fostered by the increasing need for electricity to supply PRC's growing urban centers with water, to clean up wastewater and, in northern and western PRC, to recycle wastewater for other uses. These activities require new and more powerful pumps, and electricity-hungry water treatment plants powered for the time being by coal-fired generating stations.

Producing, treating, and transporting water represent a growing dimension of the PRC's demand for electricity, and thus an expanding portion of the country's emissions of carbon dioxide, particulates, and other air pollutants.

To serve the demand for water, this study found that Urumqi operates 15 water treatment plants capable of providing 1.2 million cubic meters of water daily in the summer and 600,000 cubic meters daily in the winter. Urumqi also operates 10 waste water treatment plants, three of which manage purification equipment that recycles waste water for use in industry, to cool boilers, and in the city's gardens.

The Xinjiang Deland Engineering Center for Water Treatment, a prominent water treatment design group, estimates that treating a cubic meter of wastewater requires 1 kilowatt/hour of electricity. Treating water for drinking requires about 0.5 kilowatt/hour. Recycling wastewater for other uses requires 1.5 to 2 kilowatt/hours.

Urumqi's demand for water, wastewater treatment, and recycled water is soaring, along with its population and industrial output. It is:

- Treating 310 million cubic meters of drinking water daily, roughly twice as much as in 2000. Demand is expected to grow to 600 million cubic meters by 2015, according to city authorities.
- Cleaning up 200 million cubic meters of wastewater daily.
- Recycling 150 million cubic meters of wastewater daily for use in industrial operations.

All told, 1.5 billion kilowatt hours of electricity is needed each year in Urumqi to treat water for various uses, or roughly 10 percent of the city's power supply. That is more than the 1.39 billion kilowatt hours of electricity used by Urumqi's residents in 2011.

A 300-megawatt coal-fired generating station capable of generating that level of electricity will consume almost 1 million tons of coal, and produce tens of thousands of pounds of sulfur, nitrogen oxide, and particulates annually, and more than 2 million metric tons of carbon dioxide.

B. Major Lessons Learned

- Because moving and treating water requires considerable amounts of electricity, new methodology in PRCEE's research would likely find that reducing water consumption also will reduce primary air pollutants.

- The policy implications of applying co-control protocols across China are profound, this study finds. Mindful of the long lifetimes of power plants, the PRCEE's work to take water consumption into account in its co-control methodology would be essential in convincing China's electricity sector to be more mindful of water supply, climate change, and geography when it plans new plants.

- Co-control methodology would help energy planners and regulators anticipate and plan for potential shortages of water, and adjust the size, location, technology and fuel of energy generation projects. Planning and construction decisions made by municipalities over the next decade will produce an electrical generating industry that uses much less water, much less carbon, is more reliable, and is more capable of adjusting and resisting the affects of climate change.

IV. APPENDICES (In Separate Attachments)

Appendix A: PDA White Paper

Appendix B: PDA PowerPoint Presentation

Appendix A: White Paper

Scoping Water and Energy Pollution Nexus in Urumqi and Qingdao for Preparing PRC's Ministry of Environmental Protection Co-Control Program

Urumqi, PRC

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Circle of Blue, a project of the Pacific Institute, March 2013
J. Carl Ganter, Project Manager

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I. Executive Summary

The People's Republic of China's (PRC) 12th Five-Year Plan (2011-2015) focuses on water conservation and environmental protection as national priorities. PRC's leadership acknowledges in this plan that there is much to be done to limit pollution and secure adequate supplies of energy and water for growing northern and western cities.

Yet impeding PRC's goal of securing adequate supplies of energy and water is the country's insistence over the past decade on increasing development and GDP growth at the rate of eight percent to 10 percent annually.[1]

Swift economic development has fostered rising incomes, which, in turn, generates increased demand for energy and food. Agriculture and energy are the two largest consumers of PRC's freshwater reserves, accounting for nearly 90 percent of all the water used in PRC.[2]

But rising demand for energy and food is encountering diminishing supplies of fresh water. That is particularly true in PRC's dry northern and desert western provinces, which receive only 20 percent of the country's rainfall. Chinese hydrologists have documented a 12 percent reduction in freshwater reserves in the country's northern and western regions since 1981.[3]

PRC's coal consumption accounts for 76 percent of PRC's energy production, 70 percent of the energy consumed, and produces the world's highest emissions of carbon dioxide, a greenhouse gas that contributes to climate change.[4] The dry north is where 70 percent of PRC's coal is mined, processed, and consumed, and where a fifth of the country's grain is harvested.[5] The PRC's Climate Change White Paper justifies more aggressive policy and investment to lower greenhouse gas emissions because carbon emissions are raising temperatures and reducing rain and snowfall, thus lowering water reserves needed for energy and food production, and urban development.[6]

Simply put, according to Chinese authorities and government reports, PRC's demand for energy, particularly for coal, is outpacing its freshwater supply.[7] That, in turn, threatens the productivity of PRC's farm sector and the economic stability of its fast-growing northern and western cities. The conflicts between energy needs, and demands for food and water threatens to seriously impede PRC's economic progress.

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[1] National Bureau of Statistics, Accumulated Gross Domestic Product, 2000-2012; http://www.stats.gov.cn/english/statisticaldata/yearlydata/
[2] Ministry of Water Resources, Conserving and Protecting Water Resources; http://www.mwr.gov.cn/english/cpws.html
[3] Second National Communication on Climate Change to UNFCCC, January 1, 2012, p. 12; http://unfccc.int/resource/docs/natc/chnnc2e.pdf
[4] U.S. Energy Information Administration, *Country Analysis Brief*, October 2012; http://www.eia.gov/countries/country-data.cfm?fips=CH#cde
[5] China Coal Resource; http://en.sxcoal.com/Search.aspx?category=news&keys=coal%20production; ChinaAg, grain production statistics by province, 2011; http://chinaag.org/production/grains/
[6] Information Office of the State Council of the People's Republic of China, *China's Policies and Actions for Addressing Climate Change.* November 2011, Beijing http://www.gov.cn/english/official/2011-11/22/content_2000272.htm. See also, *China's Policies and Actions for Addressing Climate Change* (2012) The National Development and Reform Commission. http://www.sdpc.gov.cn/zjgx/W020121122593390288010.pdf
[7] HSBC Global Research, *No Water No Power*, September 2012; http://chinawaterrisk.org/notices/china-water-risk- and-hsbc-no-power-no-water-report/

PRC is aware of the conflict over water use by its largest industries, and has introduced water efficiency measures. Though PRC's economy has grew almost eight-fold from 1995 to 2010, water consumption increased only 15 percent, or 1 percent annually. [8] PRC's major cities, for example, are retrofitting their sewage treatment systems to recycle wastewater for use in washing clothes, flushing toilets, and other grey-water applications. Major industrial plants are required by the Water Law of the People's Republic of China, initially enacted in 1988 and updated in 2002, to show there is adequate water in the region to supply new factories before they are allowed to build.[9]

However, rising demand for food and energy and declining freshwater reserves potentially pose problems for PRC's continuing development:

- Production of coal has tripled since 2000 and in 2012 reached 3.44 billion metric tons. Government analysts project that PRC's energy companies will need to produce an additional 600 million metric tons of coal annually by 2020, representing a 17 percent increase. Freshwater needed for mining, processing, and consuming coal accounts for the largest share of industrial water use in PRC, or roughly 120 billion cubic meters a year, a fifth of all the water consumed nationally.[10]

- By 2020, PRC anticipates needing nearly 600 million metric tons of corn, rice, and wheat annually, which is about 5 percent more than is grown now, to feed its people.[11] To achieve the crop production targets, PRC is counting on assuring existing harvests in the dry Yellow River Basin, and increasing harvests in three northeastern provinces.[12] But the geographic shift in crop production from central PRC to the north and northeast has prompted concern among academic authorities and ordinary farmers.[13] PRC's pursuit of ever-larger harvests generates more competition for water with energy producers, and increases risks to erodible land and water quality.

- Though national conservation policies have helped to limit increases, water consumption climbed to a record 599 billion cubic meters annually in 2010, which is 50 billion cubic meters (13 trillion gallons) more than in 2000.[14] Over the next decade, according to government projections, PRC's water consumption, driven in large part by increasing coal-fired power production, may reach 670 billion cubic meters annually — 71 billion cubic meters a year more than three years ago.[15]

- PRC's total water resources are highly variable. From 2000 to 2009, for instance, total water reserves dropped 13 percent.[16] In other words PRC's water supply was 350 billion cubic meters (93 trillion gallons) less than it was at the start of the century.[17] Chinese

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[8] op.cit., footnote 1, footnote 2.
[9] Ministry of Water Resources, China Water Law; http://www.mwr.gov.cn/english/laws.html
[10] op. cit., footnote 1; US. Energy Information Administration, *Country Analysis Brief*, October 2012; http://www.eia.gov/countries/country-data.cfm?fips=CH#cde

[11] U.S. Foreign Agricultural Service, *Grain and Feed Annual*, March 2012; http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Grain%20and%20Feed%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_3-2-2012.pdf
[12] China's 12th Five-Year Plan, *Full English Version*, May, 2011; http://cbi.typepad.com/china_direct/2011/05/chinas-twelfth-five-new-plan-the-full-english-version.html
[13] Interview, Chen Yaning, Director of State Key Laboratory of Desert Oasis Ecology, Xinjiang, September 26, 2012; interview Duan Aiwang, Farmland Irrigation Research Institute, Xinxiang, June 6, 2012
[14] National Bureau of Statistics, China Statistical Yearbook, 2011.
[15] ibid.
[16] ibid.
[17] ibid.

climatologists and hydrologists attribute much of the drop to climate change, which is disrupting patterns of rain and snowfall.[18] In 2010 and 2011, national total water reserves climbed closer to normal historical levels, but they continue to drop in the arid north and west.[19]

Co-Control As Response To Reduce Coal Consumption

Researchers at PRC's Ministry of Environmental Protection's Policy Research Center for Environment and Economy (PRCEE), Beijing Normal University (BNU), and Qingdao University of Science and Technology (QUST) are developing research and industrial management practices designed to reduce PRC's dependence on coal. They are developing a methodology of "co-control" to identify and implement cost-effective control measures that reduce emissions of greenhouse gases and conventional air pollutants in a way that maximizes co-benefits. That methodology is being tested by PRCEE in Urumqi and Qingdao. The first phase of the Urumqi project ended in early March 2013. The Qingdao pilot will be fully launched in late 2013.

This report provides a detailed assessment of how the cities of Urumqi and Qingdao are grappling with the water and energy challenges. This report makes the case that the co-control pilots conducted by the Ministry of Environmental Protection (MEP) can be scaled up and duplicated in other cities, and that water use should be included in the co-control methodology.

The specific findings of this report were:

- Relevant information was collected in coordination with MEP and PRCEE that produced greater understanding about the water-energy confrontations in the PRC, and documented potential measures to address them in two geographically, economically, and ecologically distinct cities: Urumqi in PRC's dry and economically challenged northwest and Qingdao on PRC's wealthy and relatively more water-rich north-eastern coast.

- MEP researchers were provided with new information for the design of an integrated pollution co-control program in the 13th Five-Year Plan. This scoping work is an important step to develop the co-control program.

- PRCEE is laying out a research agenda to expand MEP's co-control approach to incorporate water.

- The co-control methodology was highlighted as an innovation at the city level to manage energy consumption and limit pollution, and offers a model for international engagement to help cities worldwide decrease their energy use, improve air quality, and more efficiently use water.

[18] op. cit., footnote 3.
[19] National Bureau of Statistics, China Statistical Yearbook, 2012.

II. Background

Researchers at PRC's Ministry of Environmental Protection's Policy Research Center for Environment and Economy (PRCEE), Beijing Normal University (BNU), and Qingdao University of Science and Technology (QUST) are developing research and industrial management practices designed to reduce PRC's dependence on coal. They are developing a methodology called "co-control" to identify and implement cost-effective control measures that simultaneously reduce emissions of greenhouse gases and conventional air pollutants in a way that maximizes co-benefits.

The co-control concept stems from 20-plus years of cooperation between the Ministry of Environmental Protection (MEP) and the U.S. EPA on the Integrated Environmental Strategies initiative in the mid-1990s. Following an extensive study of energy options and health benefits in Shanghai and Beijing, MEP and EPA carried out a nationwide Integrated Environmental Strategies study, which built the framework for regional air quality control efforts.[20]

Researchers at PRCEE are pursuing the US $282,000 co-control project, funded by the Energy Foundation and MEP, in collaboration with Beijing Normal University College of Environment, and Qingdao University of Science and Technology College of Environment. The intent is to investigate control targets for air pollutants and deploy various equipment, state-of-the-art industrial practices, and market mechanisms to reduce total greenhouse gas emissions. In the process of reducing those emissions, other toxic pollutants affecting the quality of urban air should also decline. The scoping work undertaken in this Asia Development Bank-supported Pilot and Demonstration Activity enabled MEP's Policy Research Center to expand their research efforts to explore 1) how to incorporate trends of water-energy conflicts into each co-control pilot city, and 2) begin developing innovative solutions to resolve them.

Urumqi, the fast-growing industrial desert city of 3 million residents in Xinjiang Uygur Autonomous Region, in PRC's far northwest region, was selected as the first pilot demonstration of the co-control methodology and proposed management practices. Qingdao, a large and modern Pacific coast city of 8 million residents in Shandong Province, was selected as the second co-control pilot demonstration project that is expected to start in 2013.[21]

The Ministry of Environmental Protection's Policy Research Center for Environment and Economy is developing alternative approaches to command and control policies that regulated pollutants individually, and to mandatory plant closures to limit air pollution and climate emissions. According to PRCEE researchers, some control methods for individual pollutants are very energy intensive and have led to significant increases in CO_2 emissions. PRCEE is taking a more holistic approach and is studying air quality improvement models that rely on science, market forces, and state-of-the-art technology and production practices.

The PRCEE's new approach was developed by Dr. Hu Tao, the PRCEE chief economist, and his team. The approach includes the following actions:

1. Analyze physical synergies of each control measure by indicators of coefficient and elasticity.

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[20] U.S. Department of State, Clean Air Action Plan Executive Summary, November 2008; http://www.state.gov/e/oes/eqt/tenyearframework/141872.htm

[21] Ministry of Environmental Protection, Policy Research Center for Environment and Economy, communication to Woodrow Wilson Center For International Scholars, December 2011.

2. Identify co-control measures that could reduce both air pollutants and greenhouse gases with the same control measures.
3. Estimate total abatement cost of air pollutants and greenhouse gasses of each control measure.
4. Find the least cost-abatement curve of co-control by ranking all co-control measures. In other words, choose the right mix of lower-cost technology and more efficient operating practices to lower costs for production and to manage waste streams.
5. Apply "life cycle" information to understand the price and operating costs of various technologies, equipment, and operating practices to reduce pollution.
6. Compel industrial operators, through market forces, to comply with PRC's tightening environmental standards.

One of the market-based models under development since 2010 is PRCEE's multi-pollutant co-control project. The co-control project's first pilot application is in Urumqi, led by Dr. Hu Tao at PRCEE. Dr. Mao Xianqiang, professor and director of the Center for Global Environmental Policy at Beijing Normal University, is the key researcher on the Urumqi project. For the past year he and his team worked with the Urumqi Environmental Protection Bureau and local research centers to gather pollution emissions and power sector data for four energy intensive and polluting industrial sectors in the city—cement, steel, chemicals, and coal-fired power plants.[22] Their access to data has been extensive and the city is providing considerable financial support to the project.

PRCEE's second research project in Qingdao will be supervised by Dr. Qian Yi, professor and dean of the School of Environment and Safety at Qingdao University of Science and Technology. The design of this project will mirror that of Urumqi, namely partnership with the municipal and provincial EPB and research centers, and gathering pollution data along three industrial sectors.

The need to reduce air pollution is more urgent in Urumqi than Qingdao. According to PRCEE's Mao Xianqiang, Urumqi has more "severe air pollution, especially during winter heating season. The pollution has already had some influence on citizen health and social stability. At present, the air quality of Urumqi falls behind most provincial capitals."[23] In fact, for the past two years, Urumqi has been the only major Chinese city to receive an air quality ranking of Level III+, and the air has the highest sulfur dioxide content of any major Chinese city.[24]

The Xinjiang Autonomous government and the Urumqi government list improving air quality as one of the principal civic goals.[25] The provincial and municipal governments plan to invest $3.2 billion (19 billion RMB) investment in combustion and pollution control equipment over the next three years to improve air quality by focusing on reducing emissions citywide of three primary air pollutants – sulfur dioxide (SO_X), nitrogen oxide (NO_X), and particulate matter (PM).[26]

All three pollutants are produced in extremely high quantities from burning coal. PRCEE emissions data are more complete for Urumqi than Qingdao. In 2009, Urumqi's power plants and heavy

[22] Mao Xianqiang, Director, Center For Global Environmental Policy, Beijing Normal University, interview with Circle of Blue in Beijing, September 28, 2012.
[23] ibid.
[24] "2012 年上半年环境保护重点城市环境空气质量状况 (Report of the Ambient Air Quality Status of Key Environmental Protection Cities for the first half of 2012)." August 20, 2012. Ministry of Environmental Protection. <http://www.mep.gov.cn/gkml/hbb/bgg/201208/W020120823509623593751.pdf>. "2011 年上半年环境保护重点城市环境空气质量状况 (Report of the Ambient Air Quality Status of Key Environmental Protection Cities for the first half of 2011)." July 22, 2011. Ministry of Environmental Protection. http://www.mep.gov.cn/gkml/hbb/bgg/201107/W020110730434018324100.pdf.
[25] op. cit., footnote 22.
[26] op. cit., footnote 22.

industries poured 156,000 metric tons of NO_X into the atmosphere. Two years later, that number had increased to 178,000 metric tons. PRCEE and municipal leaders are working together to implement co-control measures and they anticipate reducing NO_X emissions to 81,000 metric tons in 2015, or by 54.5 percent. [27]

SO_X emissions in Urumqi reached 132,000 metric tons in 2010, and particulate emissions totaled 68,000 metric tons the same year.[28] The pollution control measures and equipment investments called for in PRCEE's co-control protocols for Urumqi would, by 2015, reduce SO_X emissions to 49,000 metric tons and particulate emissions to 18,500 metric tons, or 63.9 percent and 72.2 percent, respectively.[29]

Table 1:
Urumqi Air Pollution Trends, Coal Consumption, 2000 – 2011 (Metric Tons)

Year	SOX	NOX	Particulates & Soot	Coal Consumption
2000	73,859	68,000	56,921	5,556,851
2001	86,030	80,000	63,595	6,930,167
2002	92,056	87,000	57,609	7,819,579
2003	99,872	95,000	58,428	8,358,327
2004	109,062	103,000	57,467	9,579,490
2005	121,829	116,000	63,314	10,470,236
2006	133,707	130,000	68,237	11,506,316
2007	142,478	139,000	73,098	12,582,328
2008	137,906	144,000	69,345	13,880,012
2009	133,914	156,000	66,527	13,852,181
2010	132,201	169,000	68,217	15,693,697
2011	137,011	178,000	69,688	19,408,154

Source: Urumqi Statistical Yearbooks, 2000 – 2012; PRCEE statistical data

In Qingdao, municipal air quality authorities have been working for years with the city's industrial companies to curb air pollution, principally by shutting down the oldest factories and power plants and doing more to enforce air quality regulations.[30] SO_X emissions in 2011 fell to 102,837 metric tons, down more than 52,000 metric tons from the recent peak of 155,351 metric tons in 2005 (Table 1). Particulate emissions, though, are climbing again after falling from a 2005 peak.

[27] Mao Xianqiang et. al, *NOx Total Emission Reduction Strategy: a multi-pollutant co-control perspective,* Presentation at the Sino-US Workshop on NOx Total Emission Control, September 26, 2012, Kunming, China
[28] Urumqi Statistical Yearbook 2012.
[29] ibid.
[30] Gong Lei, Associate Professor, Air Pollution Control, Qingdao University of Science & Technology, interview in Qingdao September 18, 2012; Lu Chuambin, Engineer, Qingdao Huadian Power Plant, September 21, 2012.

Table 2:
Qingdao Air Pollution Trends, Coal Consumption, 2000 – 2011 (Metric Tons)

Year	SOX	Particulates & Soot	Coal Consumption
2000	137,643	45,579	7,763,000
2001	126,937	43,741	7,931,000
2002	126,291	42,459	8,166,000
2003	130,156	38,292	8,338,260
2004	151,664	51,767	9,960,515
2005	155,351	53,457	13,042,275
2006	146,537	47,110	14,890,737
2007	122,884	38,378	15,213,503
2008	114,208	38,601	16,626,322
2009	113,625	36,556	15,927,802
2010	103,451	45,987	17,499,668
2011	102,807	42,390	16,604,994

Source: Qingdao Statistical Yearbooks, 2000 - 2012

Moreover, says the PRCEE, limiting emissions of sulfur, nitrogen, and dust—the three primary pollutants—also leads to lowering emissions of carbon dioxide, the primary climate-changing GHG.

Government officials in the Urumqi and Xinjiang Autonomous governments have been providing significant financial support to the PRCEE's research modeling project and assisting with a cooperative partnership with the provincial and municipal EPBs. The 12th Five-Year Plan calls for cleaner air nationally. And in March 2012, the State Council issued the newly revised *Ambient Air Quality Standard*. The new standard calls for much lower levels of $PM_{2.5}$ concentrations in air, and lower ozone levels, which mixes with sulfur and nitrogen emissions to form Urumqi's heavy smog. Following the severe smog incidents in northern PRC that began in late 2012, MEP issued new stricter emission standards on March 1, 2013 for six heavy polluting industries in 47 cities, including coal-fired power plants, steel, chemicals, petrochemicals, and non-ferrous metals.[31]

In 2010, the latest year for accurate figures, the PRC accounted for 9.4 percent of global GDP. The PRC also consumed 19 percent of the world's energy, and accounted for 52 percent of global iron ore imports, 46 percent of the steel production, 57 percent of the cement production, and 60 percent of global soybean imports.[32]

But as it grows economically, the PRC's industrialization and modernization is also putting extraordinary stresses on its air, water, and land. The PRC is now the world's largest source of

[31] Wencong, Wu and Juan, Du, *Emissions Limits Enhanced to Cut Pollution*, China Daily, February 21, 2013; http://www.chinadaily.com.cn/china/2013-02/21/content_16241858.htm
[32] World Bank, GDP (Current US$); <http://api.worldbank.org/datafiles/NY.GDP.MKTP.CD_Indicator_MetaData_en_EXCEL.xls>
International Energy Agency, Key World Energy Statistics 2012;
<http://www.iea.org/publications/freepublications/publication/kwes.pdf>
Javier Blas, Cynthia O'Murchu and Steve Bernard, *Iron Ore Pricing War*, *The Financial Times*, http://www.ft.com/intl/cms/s/0/3561ce38-b8e7-11de-98ee-00144feab49a.html#axzz2DYxewwZh.
World Steel Association, *Steel Production 2011*, http://www.worldsteel.org/statistics/statistics-archive/2011-steel-production.html.
"United States Geological Survey Mineral Commodity Summaries, *Cement;* http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2012-cemen.pdf
Successful Farming, *China to Boost Soybean Imports*, November 11, 2012;
http://www.agriculture.com/markets/analysis/soybeans/china-to-boost-soybe-impts_10-ar27451.
http://www.agriculture.com/markets/analysis/soybeans/china-to-boost-soybe-impts_10-ar27451.

emissions of carbon dioxide, nitrogen oxide, and sulfur dioxide. Its two largest industries – energy production and agriculture – are intensively competing with cities for diminishing supplies of fresh water, particularly in the arid north and desert northwest.[33]

2.1 Air Pollution From Coal Consumption

Since the mid-1990s, PRC's central government leadership has issued targets, policies, and regulations intended to reduce limits on air pollutants under the 1987 Air Pollution Prevention and Control Law, which was amended in 1995 and again in 2000. PRC's air pollution policies and regulations call for the supervision and management of dust and soot, waste gas, and toxic emissions. It establishes national air quality standards to protect public health that are enforced by provincial and local authorities, who also have the authority to enact more stringent standards than those promulgated by the central government.

The air quality law sets out broad outlines for local oversight and for coordination with industry and other agencies to reduce pollution. The law also requires new construction projects to prepare environmental impact statements and include projected impacts on air quality. The law set fines for violations and criminal sanctions to be imposed in cases of serious harm caused by air pollution.[34]

Though it is largely modeled on the air quality policies and regulations developed in the United States, the PRC applies and enforces its air pollution law differently.

The ambient air quality standards in the United States and other western industrialized nations are stricter than in the PRC. For example, PM 2.5 concentrations that would be rated "unhealthy" in the United States, are only rated "unhealthy for sensitive groups" in the PRC.[35] Thus, PRC's urban air quality, is not as good as found in some countries.

PRC has long sought to make the case that its air quality is improving. National and provincial figures, collected on an annual basis, reflect the number of days that the provincial and national governments state that levels of dust and toxic compounds are at moderate levels. There have been steady increases in the number of days that air quality is said by the government to be "good."[36]

The government assessment of air quality deemed "good" is based on its nation- specific definition. Chinese categorization of "good" air would be considered poor quality in the United States and other industrialized western economies.

During the winter of 2013, soot and particulates exceeded the highest levels on air quality monitors in several cities, posing a public health danger in the PRC.[37]

The country's emissions of carbon dioxide and other greenhouse gases are climbing with the increasing use of coal as a source of fuel, the increasing use of coal to supply the coal-to-chemicals industry, and the PRC's high rate of economic growth. According to UN data, the PRC's CO_2 emissions averaged 7 percent yearly growth between 1999 and 2009—totaling to a 56 percent

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[33] Circle of Blue, *Choke Point: China,* 2011; www.circleofblue.org/chokepointchina.
[34] Alford, William J. and Liebman, Benjamin L, Hastings Law Journal, *Clean Air, Clean Processes: The Struggle Over Air Pollution Law in the People's Republic of China*, March, 2001; http://www.wcfia.harvard.edu/sites/default/files/676__CLEAN_AIR_5_03.pdf
[35] "China's new Air Quality Index: How does it measure up?" Angel Hsu. http://hsu.me/2012/03/chinas-new-air-quality-index-how-does-it-measure-up/
[36] op. cit., footnote 22.
[37] Rong, Zhou, China Daily, *Air Pollution Needs Urgent Action*, March 1, 2013; http://www.chinadaily.com.cn/cndy/2013-03/01/content_16265707.htm

increase over the decade. The PRC's GDP grew more than 10 percent annually during the same time period.[38]

2.2 Co-Control Methodology Developed

In Urumqi, the PRCEE, BNU, and QUST researchers under the leadership of Dr. Hu Tao in cooperation with municipal officials, are currently studying the use of co-control methodology to multiple pollutants to determine its effectiveness in lowering emission control costs, and its feasibility in limiting pollution. In practice, though, achieving the dual goals of lowering costs and emissions with a theoretical model requires research, analytical analysis, consensus building in government and industry, and engineering.

Data have been collected by PRCEE regarding production, materials, and emissions for the major plants in Urumqi's four largest industrial sectors—coal-fired thermoelectric power and steam heat producers, steel manufacturing, chemical processing, and cement manufacturing. This included:

- One major steel plant.
- Five major coal-fired power plants, along with several of the more than 1,000 smaller coal-fired steam heat boilers scattered around the city.
- Ten cement plants.
- Ten chemical plants.

Data have also been collected regarding the city's transportation network, which has developed into a major air polluter because of the sharp increase in the number of cars, trucks, and buses.

In Urumqi, the number of private vehicles reached 440,627 in 2011. In 2000, there were 93,056 private vehicles.[39]

As in the United States, conventional regulations focused on single pollutants produced unexpected outcomes when it came to controlling primary air pollutants and carbon dioxide. For example, one of the popular global techniques to control sulfur emissions from industrial plants is to install equipment in the air waste stream to remove the pollutant. But the flue gas desulfurization process (FGD) itself consumes considerable amounts of electricity, powered by coal.[40]

For every kilogram of sulfur dioxide removed from the waste emissions of a power or manufacturing plant, initial calculations indicate that it:

1. Consumed 3.67-kilowatt hours of electricity;[41]
2. Used 1.182 kilograms of coal;[42]
3. Produced 5.43 kilograms of carbon dioxide;[43] and,
4. Produced .016 kilograms of nitrogen oxides.[44]

[38] op. cit, footnote 3, page 10; "Carbon Dioxide Emissions" Millennium Development Goals Indicators. United Nations. http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid=
[39] op cit., footnote 27.
[40] op.cit., footnote 22.
[41] ibid
[42] ibid
[43] ibid
[44] ibid

In other words, using the conventional approach to removing sulfur would have the boomerang effect of increasing carbon dioxide and other air pollutants. The team calculated that if all of PRC's flue gas desulfurization equipment at its coal-fired utilities functioned well, much of the sulfur emissions would be controlled.[45]

But it also would:

1. Increase electrical power generation by 3,000 to 8,000 megawatts, or the amount of power generated by three to eight big coal-fired power plants;[46]
2. Increase the use of coal by 10 million to 28.1 million metric tons annually;[47]
3. Produce 45.9 million to 129 million metric tons of carbon dioxide annually;[48] and,
4. Increase nitrogen oxides by 135,000 to 381,000 metric tons annually.[49]

Similarly, the conventional approach to reduce nitrogen emissions is to apply "selective catalytic reduction" (SCR), which is equipment powered by electricity.[50] Reducing PRC nitrogen oxides emissions by 15 percent annually, calls for taking 1.297 million metric tons of NO_X out of the air waste stream.[51]

That, however, would:

1. Require 2.579 billon kilowatt hours of electricity;[52]
2. Use 830,000 metric tons of coal;[53]

Controlling pollutants one by one, based on conventional emissions control practices, may not work to improve efficiency and reduce carbon emissions in the PRC.[54] PRCEE researchers maintain that a systematic approach could work better, especially when it is tied to advanced engineering and cost abatement. Cost abatement curve models that follow technology and design, and identify the price points at which pollution reduction is maximized at the lowest price may be the most efficient.

2.3 A Plan For Co-Control In Urumqi

In Urumqi, the PRCEE team developed a cost-effective plan to reduce SO_X, NO_X, $PM_{2.5}$ emissions, and carbon emissions at a large power plant. They:

1. Analyzed the efficiency and cleanup capacities of various practices and equipment.[55]
2. Calculated the cost of buying and operating the equipment against how much SO_X, NO_X, and $PM_{2.5}$ would actually be removed from the waste stream.[56]
3. Calculated the amount of power needed to operate the equipment and processes.[57]
4. Produced a matrix of options from which operators could choose to achieve pollution reductions.[58]

[45] ibid.
[46] ibid.
[47] ibid.
[48] ibid.
[49] ibid.
[50] ibid.
[51] ibid.
[52] ibid
[53] ibid.
[54] ibid.
[55] ibid.
[56] ibid.
[57] ibid.
[58] ibid.

For example, meeting new air quality limits in a power plant would involve installing equipment that improved efficiencies at every stage of the power production process, including:

1. Changing coal-washing equipment, which improves the quality and energy content of coal, with equipment that uses less water, and therefore less electricity to power pumps.
2. Modernize the boiler ignition systems to use less power.
3. Making sure the equipment to produce electricity and to use the waste heat to generate steam is operating with ultra high-efficient combined heat and power processes.
4. Looking for and fixing leaks in seals.
5. Changing boiler systems to incorporate integrated gasification or ultra super critical technologies that produce more power with less coal and less water.
6. Substituting smaller boiling units that tend to be more efficient and less expensive to operate for larger boilers.[59]

PRCEE researchers have applied the co-control methodology to regional scenarios to understand the effects of reducing pollution in the nation's steel industry, and to limit carbon emissions nationally. The results of these analyses indicate that significant reductions in carbon emissions can be attained by focusing on reducing sulfur dioxide and nitrogen oxide emissions. By focusing on reducing those two pollutants, PRCEE researchers calculated they would achieve reductions in carbon dioxide and methane emissions.[60] For instance, PRCEE calculated that setting a 40 percent annual reduction goal for sulfur dioxide emissions nationally would lead to a 15 percent reduction in nitrogen oxides and a 17 percent reduction in carbon dioxide emissions.[61] This translates into 12.4 million metric tons of sulfur dioxide, 7.9 million metric tons of nitrogen oxide, and 1.15 billion metric tons of carbon dioxide in emissions reductions annually.[62]

[59] ibid.
[60] ibid.
[61] ibid.
[62] ibid

Figure 1: Selected Development and Environmental Indicators for Urumqi 2000-2011

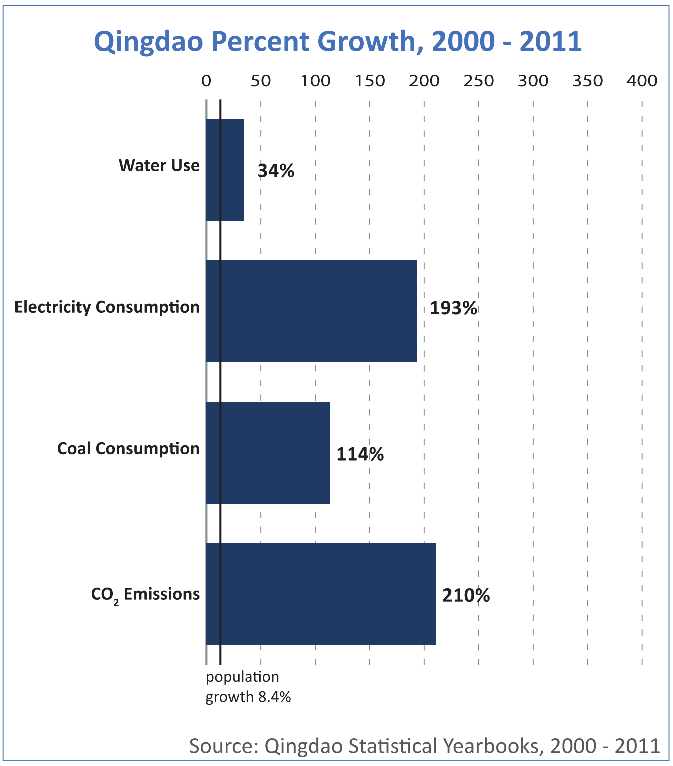
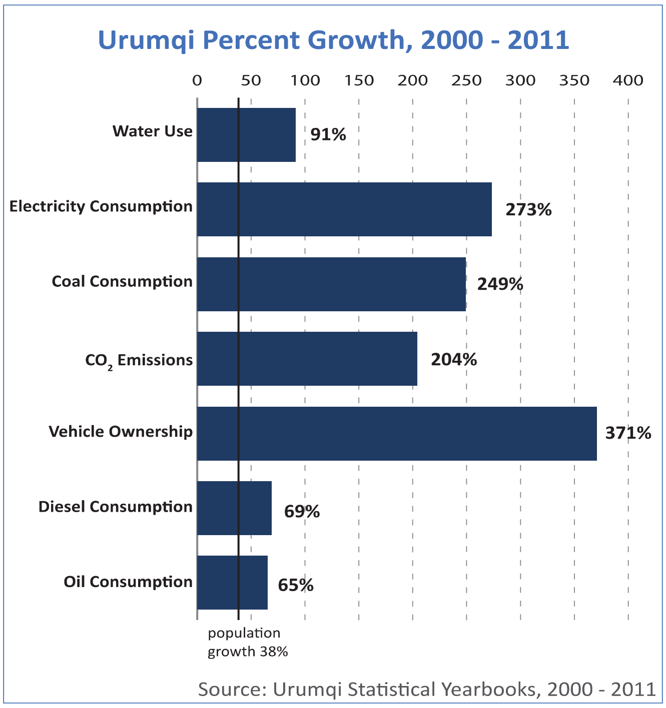


Figure 2: Selected Development and Environmental Indicators for Qingdao 2000-2011



III. Methods

A three-person team of researchers from COB collaborated with PRCEE researchers. A total of 19 days was spent by COB interviewing experts and collecting data in Qingdao and Urumqi. The COB team spent four days in Qingdao in June 2012, and six more days in September 2012. The COB spent 9 days in Urumqi in September 2012. PRCEE conducted additional meetings for a week in January, during which time the staff made presentations of their co-control work to provincial and municipal environmental and planning agencies.

COB prepared a comprehensive list of questions (see appendix 1 for the questionnaire) to apply to its data gathering in Urumqi and Qingdao, and to guide its interviews. The comprehensive list proved valuable in amassing the facts that support this report's findings.

COB conducted formal interviews with 26 individuals representing 20 research organizations, municipal and national government agencies, utilities, and universities (see appendix 2 for the list of institutions). Data were collected on energy consumption, water supply, and planned tradeoffs between use of water for energy production and other uses, including agriculture.

In conducting its field research in Urumqi and Qingdao, COB focused on the value of incorporating the water sector as a point of research and reference for PRCEE's co-control methodology to limit emissions of sulfur, nitrogen, particulates and carbon. Methane was not included in PRCEE co-control research. The second primary focus of this research project was the coal sector, and the steps Urumqi and Qingdao may be taking to reduce their consumption of coal, which also has the effect of reducing demand for water.

A third objective of this study that shaped interviews and data gathering was to understand the influence that water transport, water treatment, water recycling and other energy-intensive uses of water plays in coal consumption and air pollution in Urumqi and Qingdao.

IV. Findings

The findings of this report are based on interviews with municipal leaders, business executives, academic experts, and energy and water sector managers in both cities, plus official government statistics and literature review.

Urumqi and Qingdao are fast-growing cities with critical water shortages. Water scarcity is increasing due to multiple causes, including increased demand, inefficient use, and climate change. The number of residents and industrial plants is growing steadily in both cities.[63]

Urumqi has benefited from investments under the PRC's 1998 Go West Campaign, which has aimed to promote economic growth in the PRC's poorer inland regions.[64] The infrastructure investments

[63] Qingdao Statistical Yearbook, 2012, op. cit., footnote 27.
[64] Elizabeth Economy, *China's Go West Campaign: Ecological Construction or Ecological Exploitation*, China Environment Series Issue 5, 1-28.

have been a major draw for in-migration into Xinjiang.[65] Urumqi's population in 2011, slightly over 3 million, is nearly twice what it was in 2000.[66]

Meanwhile, Qingdao's 2011 population, 8,000,000, is growing by almost 80,000 residents a year.[67] Industrial plants, a major source of water and energy consumption have also grown considerably in Urumqi and Qingdao over the past decade—both cities have expanded the number of chemical, cement, and steel plants over the past decade, most of which operate outside the urban core.

Both Urumqi and Qingdao face water shortages. The increase in the number of citizens in both cities, as well as the number of industrial, manufacturing, and power plants that consume water, has expanded. The demand for water, and the demand to treat and recycle wastewater, is growing. So is the amount of electricity, and thus coal-fired energy, required to transport and treat water.

4.1 Urumqi Water

Urumqi's total water supply measures about 1 million cubic meters per day, or 350 million cubic meters annually. Water demand in Urumqi has grown 122,000 cubic meters a day since 2009, or more than 3 percent annually. [68] Urumqi's water is supplied by snow- and glacial melt in the nearby Tian Shan Mountains that is stored in a network of 18 reservoirs that ring the city, and recharges the city's groundwater.

Some 43 percent of the city's water supply is pumped from aquifers that are steadily dropping because recharge rates are not keeping pace with use, according to the Municipal Water Management Bureau.[69] The remaining 57 percent is surface water collected in a system of reservoirs that ring the city.[70] Both the underground and surface reserves are supplied from water the city collects from snowmelt and a big glacier in the nearby Tian Shan Mountains. Water is transported through a network of concrete canals. Because of climate change, the glacier is steadily receding and the snow line is retreating to higher elevations.[71]

Of the total water supply, 64 percent is used on farms, 21 percent in residences, and 15 percent in industries.[72]

To serve the demand, Urumqi operates 15 water treatment plants capable of providing 1.2 million cubic meters of water daily in the summer and 600,000 cubic meters daily in the winter. Urumqi also operates 10 waste water treatment plants, three of which manage purification equipment that recycles waste water for use in industry, to cool boilers, and in the city's gardens.[73]

Evidence of water scarcity is found in and around the city. South of Urumqi, thousands of hectares of irrigated cropland, most of which produced cotton, have reverted to grass and scrub because of falling water tables. As recently as 15 years ago, water was less than 60 meters beneath the surface.

[65] Preeti Bhattacharji, *Backgrounder: Uighurs and China's Xinjiang Region*, Council on Foreign Relations; http://www.cfr.org/china/uighurs-chinas-xinjiang-region/p16870
[66] op.cit., footnote 27.
[67] Qingdao Statistical Yearbook, 2012.
[68] Wang Xiufeng, Director, Design and Planning Bureau, Urumqi Municipal Water Management Bureau, interview, September 28, 2012.
[69] Urumqi Municipal Water Bureau.
[70] ibid.
[71] Chen Yaning, Director, State Key Laboratory of Desert Oasis Ecology, interview in Xinjiang, September 28, 2012.
[72] Wang Xiufeng, Director, Design and Planning Bureau, Urumqi Municipal Water Management Bureau, interview, September 28, 2012.
[73] ibid.

Pumps sucked the water out of the ground, using 1 kilowatt-hour of electricity to pump 1 cubic meter to the surface.[74]

Today, that same water lies 120 meters deep. It now takes 2 kilowatt-hours of electricity to pump a cubic meter of water to the surface, say water supply authorities.[75] Doing so requires larger pumps and bigger energy budgets. Since 2004, cotton producers have steadily abandoned the land because of the higher costs.[76]

4.2 Qingdao Water

Qingdao's total water reserve amounts to 2.2 billion cubic meters. The city uses about 380 million cubic meters annually, about 65 percent of which is supplied from a canal that stretches from the Yellow River to the city.[77] The balance is supplied from the 688.2 millimeters of rain that falls in an average year, and stored in four reservoirs, and from groundwater. [78]

Water reserves, though, are falling. In 2000, when the population of the city was 1 million less than today, Qingdao had 1.05 billion cubic meters of water available for use. By 2005, the city's water supply available for use fell to 960 million cubic meters.[79]

Meanwhile demand is increasing. The city's daily water supply is 850,000 cubic meters, or about what the city used in 2010. By 2020, water demand is expected to grow to 940,000 cubic meters daily. This leaves a potential shortfall of 90,000 cubic meters of water a day that the city simply does not have.[80]

Of the total water used in Qingdao, 42 percent is used in agriculture, 25 percent in residences, 16 percent in industry, and 13 percent for public use in gardens and parks.[81]From 1990 to 1998, water use in Qingdao increased 5.35 percent annually, according to Qingdao Municipal Engineering Design and Research Institute. From 1998 to 2007, water use in the city increased 12 percent annually.[82]

Today, the city:

1. Treats 340 million cubic meters of drinking water annually, 50 percent more than in 1995.[83]
2. Cleans up 105 million cubic meters of wastewater annually.[84]

Both figures are increasing by three to five percent a year.[85]

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[74] op.cit., footnote 70, Kejiang Zhang, Chief Engineer, Xinjiang Deland Engineering Center For Water Treatment, interview September 27, 2012.
[75] ibid.
[76] op.cit., footnote 70.
[77] Cui Junling, Chief Engineer, Qingdao Hydrology Bureau, interview, September 17, 2012.
[78] ibid.
[79] ibid.
[80] Mei Yading, Water Treatment Engineer, Qingdao Municipal Engineering Design and Research Institute, interview September 17, 2012.
[81] ibid.
[82] ibid.
[83] ibid.
[84] ibid.
[85] op cit., footnote 68.

To meet the water needs for Qingdao, the city operates 33 drinking water treatment plants. Qingdao has plans to build 10 very energy-intensive desalinization plants over the next 5 years.[86]

Most of the city's water supply -- about 240 million cubic meters annually – is transported from the Yellow River under a quota system overseen by the provincial government.[87]The balance of Qingdao's water comes from the 700 millimeters of rain that falls on the province in a typical year.[88]

4.3 Electricity and Water

Supplying, treating, and using water requires substantial amounts of electricity. Although no studies have yet formally examined electricity requirements for moving and treating water in the PRC, there have been some studies in the United States. One study estimates that water uses 13 percent of the electricity in the United States.[89] The energy footprint of California water is even higher at 19 percent.[90]

In Qingdao and Urumqi most energy comes from coal. Thus, as the two cities increase their development of water transfers, water treatment, and—in the case of Qingdao—desalinization, their carbon footprint is likely to grow too.

PRCEE co-control methodology could be expanded to help estimate and reduce the carbon foot print, and to provide systematic evidence to support more aggressive water conservation and cleaner energy development.

With the exception of a novel waste heat recycling and a coal-conserving heat transfer project at a coal-fired power plant in Urumqi, as well as the construction of a liquid natural gas import terminal in Qingdao, we found that coal consumption in both Urumqi or Qingdao was steadily increasing. Part of the reason is the rising demand for electricity to transport and treat water for drinking, limit pollution, and to recycle waste water.

Urumqi Coal Consumption

The coal sector—production, consumption, and combustion—accounted for 120 billion cubic meters of PRC's water use in 2010, or 20 percent of all domestic water use.[91] Most of the coal the PRC produces is used to generate electricity and heat.

Urumqi's annual demand for coal is 22 million tons a year, of which 19.4 million metric tons is needed to power electrical generating and industrial plants. In 2000, Urumqi's industrial demand for coal was 5.5 million metric tons.[92]

Qingdao consumed 16.6 million metric tons in 2011, more than twice as much coal as the city consumed in 2000.[93]

It takes roughly 2.5 liters to twelve liters of water to generate a kilowatt-hour of electricity, according to the PRCEE and the U.S. Department of Energy.[94] The PRC Ministry of Water Resources

[86] ibid.
[87] op.cit., footnote 81
[88] ibid.
[89] Bevan Griffiths-Sattenspiel and Wendy Wilson, Carbon Footprint of Water, River Network, 2009; http://www.rivernetwork.org/resource-library/carbon-footprint-water
[90] See footnote 33.
[91] op. cit., footnote 19.
[92] op. cit., footnote 27.
[93] op.cit.,

estimates that the nation's annual water use will increase from 600 billion cubic meters in 2010 to as much as 670 billion cubic meters in 2020.[95] The largest share of that increase—15 billion cubic meters (4 trillion gallons) a year—is due to the increase in coal mining and processing, along with cooling coal-fired power plants.

In 2011 PRC generated 4.6 trillion kilowatt hours of electricity, more than any nation. PRC's economic development authorities project that the PRC's power demand will roughly double by 2020.[96]

The Xinjiang Deland Engineering Center for Water Treatment, a prominent water treatment design group, estimates that treating a cubic meter of wastewater requires 1 kilowatt/hour of electricity. Treating water for drinking requires about 0.5 kilowatt/hour. Recycling wastewater for other uses requires 1.5 to 2 kilowatt/hours.[97]

Urumqi's demand for water, wastewater treatment, and recycled water is soaring, along with its population and industrial output. It is:

1. Treating 310 million cubic meters of drinking water daily, roughly twice as much as in 2000. Demand is expected to grow to 600 million cubic meters by 2015, according to city authorities.[98]
2. Cleaning up 200 million cubic meters of wastewater daily.[99]
3. Recycling 150 million cubic meters of wastewater daily for use in industrial operations.[100]

All told, 1.5 billion kilowatt hours of electricity is needed each year in Urumqi to treat water for various uses, or roughly 10 percent of the city's power supply.[101] That is more than the 1.39 billion kilowatt hours of electricity used by Urumqi's residents in 2011.[102]

A 300-megawatt coal-fired generating station capable of generating that level of electricity will consume almost 1 million tons of coal, and produce tens of thousands of pounds of sulfur, nitrogen oxide, and particulates annually, and more than 2 million metric tons of carbon dioxide.[103]

4.4 Power Generation, Water Treatment, Transport, and Air Quality

In Qingdao the percentage of days when air is regarded as "excellent or good," has improved more than 1 percent annually for at least a decade. In 2011, the number of days measured as "excellent or good" reached 91.5 percent, 0.8 percent better than the 90.7 percent "excellent or good" air quality days in 2010.[104]

Much of the improvement has come as a result of shutting down old, inefficient, and polluting industrial plants in the urban core, and constructing cleaner modern plants close by in rural districts outside Qingdao. The major contribution is from end-of-pipe technology engineering control measures to reduce emissions. For example, every newly established power plant in the

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[94] EPRI, *U.S. Water Consumption For Power Production*, 2002; NREL, *Consumptive Water Use For U.S. Power Production,* 2003.
[95] op. cit, footnote 12.
[96] ibid.
[97] op. cit., footnote 75.
[98] op.cit., footnote 72.
[99] ibid.
[100] ibid.
[101] op. cit., footnote 75.
[102] ibid.
[103] Union of Concerned Scientists, *How Coal Works*, http://www.ucsusa.org/clean_energy/coalvswind/brief_coal.html
[104] Qingdao Statistical Yearbook, 2012.

PRC is required by law to install flue gas desulfurization (FGD) technology, which reduces SO_2 but increases CO_2.[105]

According to the Qingdao University of Science and Technology, authorities have closed 297 small coal-fired industrial boilers and 15 small coal-fired industrial power plants since 2007. In addition, authorities ordered the closure of 10 chemical plants and eight inefficient production lines at cement, fertilizer, and paper plants.[106]

In Urumqi, environmental managers rated 233 days in 2012 as "good," seven more than in 2011. The same managers rated 279 days in 2012 as "fairly good" in air quality terms, three more than in 2011.[107] The goal in Urumqi is to reach 300 "fairly good" air quality days in 2015. The *China Daily* reported a decline in respiratory illness, stating that in November, 2012, "1,983 people were seen at the outpatient department of the People's Hospital of the Xinjiang Uygur Autonomous Region for respiratory problems, compared with 2,711 in the same month last year."[108]

Urumqi utility and environmental managers say that one of the biggest factors in the campaign to reduce air pollution is the number of small coal-fired boilers that are fired up in winter to produce steam for heating. These small boilers operate without pollution control equipment. Moreover, as the city's population increases, so do the number of small coal-fired steam boilers. This rise in boilers, in turn, has increased the quantity of coal burned in Urumqi during the winter when air pollution, as measured by a monitor overseen by the U.S. Embassy, frequently reaches the 400 zone or seriously hazardous to human health.[109]

In 2005, steam boilers in Urumqi consumed 1.25 million metric tons of coal. By 2011, that number reached 1.71 million metric tons. Steam boilers are part of the reason that Urumqi has not effectively regulated the growth in total emissions of carbon dioxide and other GHG gases. In 2011 Urumqi's carbon emissions reached 60.8 million metric tons, more than three times the amount in 2000.[110]

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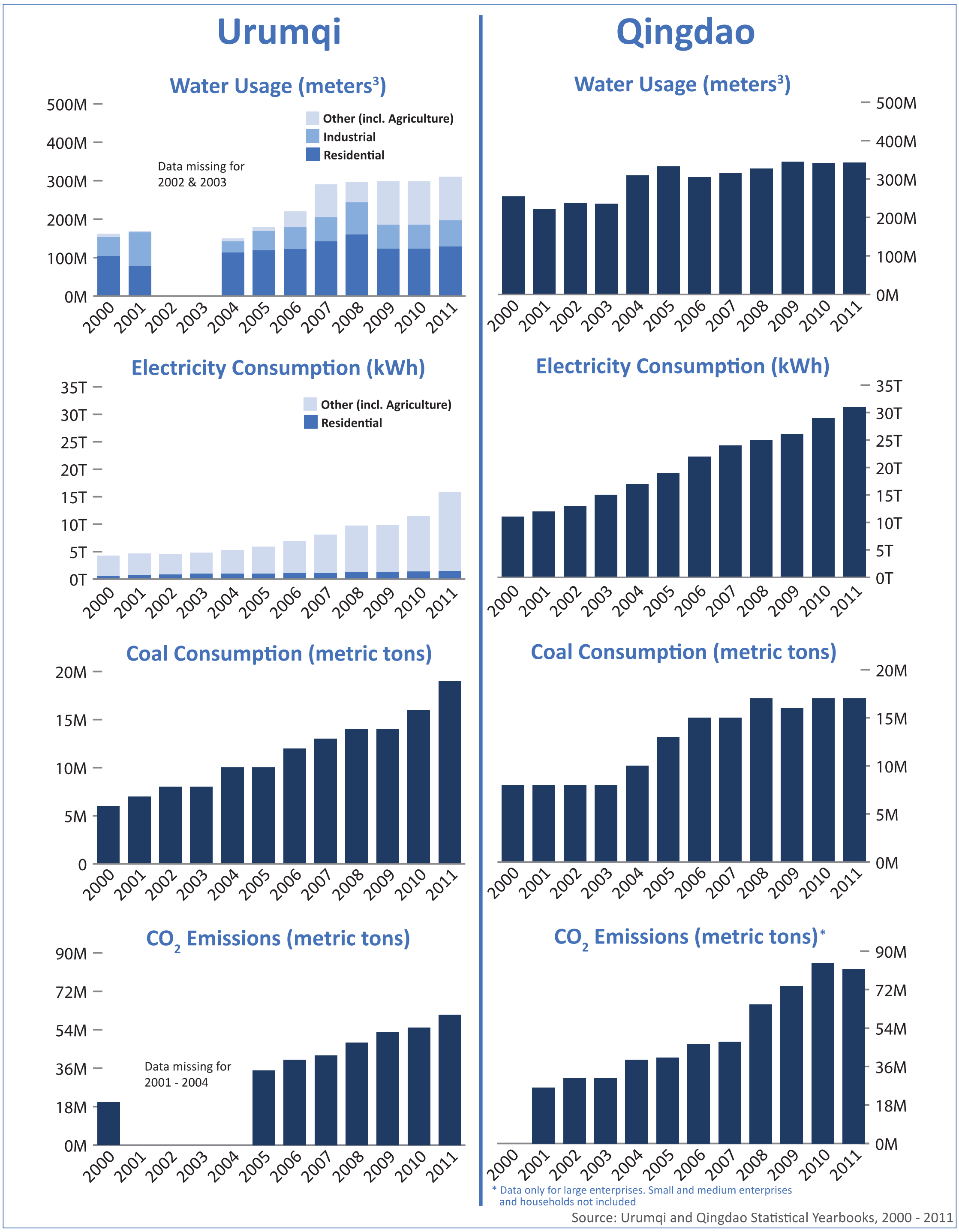
[105] Hudian Long, Assistant Director of Production, Xinxiang Huadian Power Plant, interview September 24, 2012.
[106] Zhou Guizhong, Associate Professor, Qingdao University of Science and Technology, interview June 6, 2012.
[107] op. cit., footnote 27.
[108] Shao Wei, *Sun Shines on Urumqi Anti-Pollution Projects*, *China Daily*, December 12, 2012; http://www.chinadaily.com.cn/china/2012-12/19/content_16030443.htm
[109] U.S. Embassy particulate monitoring data.
[110] op. cit., footnote 27.

Figure 3: Water and Energy Statistics for Urumqi and Qingdao, Compared, 2000-2011
(M = million metric tons; K = trillion kilowatt hours)



V. Discussion

The electricity required to transport and treat water in PRC's growing cities is a vital area of research for PRCEE to consider. So is the growing contest for the PRC's fresh water reserves—which are declining. The priority to address water-coal confrontations in the PRC has recently been recognized by top- level policymakers in the 12th Five-Year Energy Development Plan that was released January 2013. In the coal subsection II of the this plan, water resource constraints linked to coal power were mentioned for the first time in a five-year plan, highlighting the major challenge of addressing water overuse and pollution linked to coal production.

The objectives and findings of this research white paper and accompanying Power Point presentation are meant to help PRCEE researchers to start broader conversations about energy production and water supply with colleagues at their center and MEP, as well as in Urumqi, which would then give them input on designing future research.

That research is urgent.

As this study shows, a portion of PRC's new demand for power is fostered by the increasing need for electricity to supply PRC's growing urban centers with water, to clean up wastewater and, in northern and western PRC, to recycle wastewater for other uses. These activities require new and more powerful pumps, and electricity-hungry water treatment plants powered for the time being by coal-fired generating stations.

Urumqi and Qingdao authorities recognize the conflict over scarce water supplies. Farmers have closed down irrigated cropland outside Urumqi. City officials more carefully weigh the water demands of new industrial plants. A proposal to build a coal-to-chemicals manufacturing base near Urumqi has encountered stiff opposition from city authorities worried about the millions of cubic feet of water it would need to operate.

The Wei Huadian Power Plant, a 250-megawatt coal-fired generating station in Urumqi, modernized its turbine systems, and uses 14 percent less coal to generate a kilowatt-hour, and therefore less water. The plant also installed a heat pump in its boiler system that saves 30,000 to 50,000 cubic meters of water a year.

Urumqi also is significantly increasing investment in wastewater recycling plants. The treated water is used by industries, to water gardens, and as gray water to flush toilets. In 2013, the city opens its newest water recycling plant, which will more than triple the amount of water cleaned up to over 100 million cubic meters from 30 million cubic meters in 2012.

Though the electrical generating network is essential to every aspect of the PRC's economy and way of life, the generating network's favored carbon-based fuel sources also have made its operations less fit for the era of hotter and dryer weather occurring in the PRC.[111] Most power plants require access to large volumes of water in order to generate electricity, thus erratic climate conditions are making it much more difficult for utilities to consistently supply electricity to the rapidly expanding number of residences and businesses in Urumqi, Qingdao, and other Chinese metropolitan regions.

Given increasing demand for electricity production and, therefore water, applying energy generation technologies that reduce water use, and limit climate-changing emissions, warrants

[111] op. cit., footnote 3.

serious consideration. Depending on what mix of technologies and fuels are deployed, the amount of water withdrawn from lakes, rivers, and underground aquifers to produce steam and cool plants could drop.

A conventional 500-megawatt coal-fired plant burns 250 tons of coal per hour, and uses 12 million gallons of water an hour — 300 million gallons a day — for cooling, according to researchers at Sandia National Laboratories.

Broken down to specific technologies, water consumption in:

- Nuclear power plants – 43 gallons per kilowatt-hour.
- Coal-fired plants – 36 gallons per kilowatt-hour.
- Natural gas-fired plants –15 gallons per kilowatt-hour.
- Wind power – negligible water use.
- Solar photovoltaics – negligible water use.

Climate variability and the need to reduce GHG emissions could lead to a dynamic, sector-wide transition in electrical supply that more readily fits the conditions that the PRC faces. PRC's utilities and government regulators have critical decisions to make in 1) locating and building new generating systems, 2) determining fuel choices, 3) assessing power demands, and 4) ensuring that across a landscape where confrontations over water are growing more numerous, power plants, as well as other sectors, have adequate supplies to operate.

By no means is this an improbable goal. In fact, if assumptions made for the US and Europe hold for the PRC, an electrical supply system that conserves water should be achievable, could dramatically reduce climate-changing emissions, and lower operating costs and prices for electricity.[112]

Making the wrong choices in electricity supply technologies and fuels, though, would have a significant negative environmental impact. Energy demand and water supply is uneven across the PRC.[113] The north and northwest, two of the fastest growing regions in the PRC, are threatened by long-term drying conditions. From 2000 to 2010, Xinjiang's population increased from 19.25 million to 21.8 million, or 13.2 percent. Urumqi's population in 2010—3.1 million—is 38 percent higher than in 2000. The PRC's population during tne same decade increased 5.5 percent.[114] Xinjiang's total water resources, largely as a result of climate change, say Chinese researchers, also have become erratic even as population grows. In 2007, a relatively wet year, precipitation in Urumqi reached an average of 419.5 millimeters. In 2010, rain and snowfall dropped to 282.5 millimeters.[115] Such figures reflect an overall drying trend in the province, which spans 1.66 million square miles and is second largest behind Tibet. In 2002, Xinjiang's aquifers received 72.48 billion cubic meters of water to recharge groundwater supplies. By 2011, aquifer recharge water supplies measured 54 billion cubic meters. [116]

Similar trends in population also have occurred in the PRC's central coast region. From 2000 to 2010, Shandong's population increased from 89.97 million to 95.8 million, or 12.2 percent. Shandong is the PRC's second most populous province. Qingdao's population in 2010—8.7

[112] van Vliet et. al., Nature Climate Change, June 3, 2012;http://www.nature.com/nclimate/journal/v2/n9/full/nclimate1546.html
[113] op. cit., footnote 3.
[114] National Bureau of Statistics, 2012.
[115] National Bureau of Statistics, 2011.
[116] National Bureau of Statistics, 2012.

million—is more than twice what it was in 2000, when the city counted 2.7 million residents.[117] Shandong's total renewable water resources, though, amount to 347.6 billion cubic meters per year, resulting in an average of 361.6 cubic meters per capita, the lowest of any of the PRC's large industrial provinces. Climate change is drying the province. In 2007, a wet year, average annual rainfall in Qingdao measured 942.3 millilmeters. Rainfall steadily declined since and in 2012 measured 591.3 millimeters.[118] Water use in the province has fallen from 25 billion cubic meters in 2002 to 23 billion cubic meters in 2010, an eight percent decline.[119]

Unless utilities and government planners carefully evaluate the new hydrological trends and make clear choices for water-conserving generating technology and fuels, the economies, quality of life, and environment in these regions could deteriorate.

Market trends, increasing energy efficiency, and increased use of cleaner fuels -- including natural gas – indicate, however, that generating electricity could result in significantly less water consumption by 2050 than the industry's current operating regime, dominated by water-cooled coal-fired power plants. The PRC's 12th Five-Year Plan, for instance, calls for reducing the percentage of electricity generated from coal combustion from 70 percent in 2010 to 65 percent in 2015.[120] The latest Five-Year Plan also calls for increasing the share of renewable and non-fossil generating capacity to 30 percent by 2015, from 21 percent in 2010. One important indicator of the rising influence of non-fossil fuel generating capacity occurred in 2012, a year that wind generated 100.4 terra-watts of electricity, 35.5 percent more than in 2011.[121] The increase in coal-fired electricity from 2011 to 2012 was 0.3 percent. Wind generators also produced more electricity in the PRC in 2012 than the 98 terra-watt hours generated by nuclear plants.[122]

Mindful of the long lifetimes of power plants, the PRCEE's work to take water consumption into account in its co-control methodology would be essential in convincing the PRC's electricity sector to be more mindful of water supply, climate change, and geography when it plans new plants.

Co-control methodology would help energy planners and regulators anticipate and plan for potential shortages of water, and adjust the size, location, technology and fuel of energy generation projects. Planning and construction decisions made by municipalities over the next decade will produce an electrical generating industry that uses much less water, much less carbon, is more reliable, and is more capable of adjusting and resisting the affects of climate change.

An air pollution co-control policy dialogue between PRCEE team and the Xinjiang Environmental Protection Department Director-General was held on March 17, 2013 in Urumqi. The dialogue included a discussion of this ADB-supported PDA in order to raise the issue of water being incorporated into co-control pilots. PRCEE researchers with continued are planning to conduct further research for implementing a co-control plan in Urumqi and expand the pilot work to Qingdao and Chengdu.[123]

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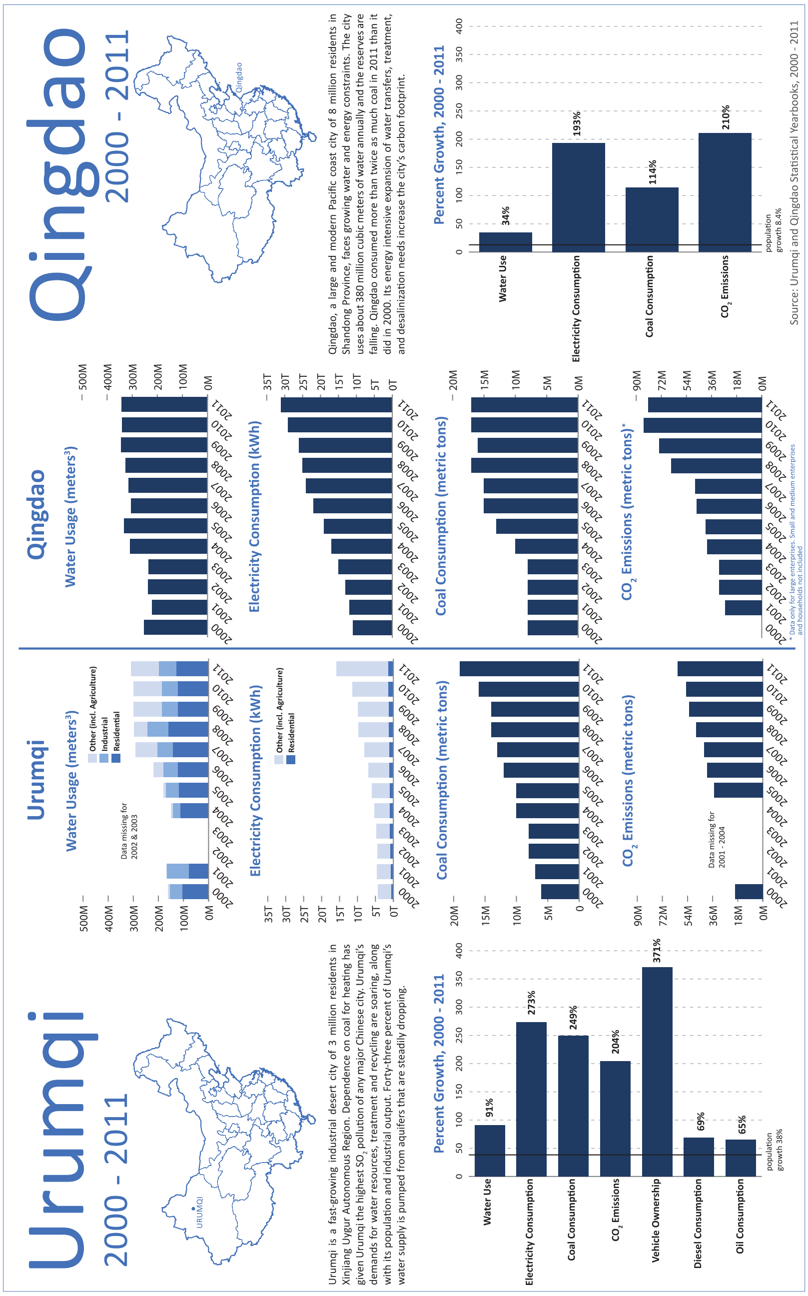
[117] Ibid.
[118] Ibid.
[119] Ibid.
[120] PRC 12th Five-Year Plan, 2012.
[121] Li Shuo. "China's Wind Power Production Increased More Than Coal Power Did For First Time Ever In 2012." Climate Progress. March 20, 2013. http://thinkprogress.org/climate/2013/03/20/1744741/chinas-wind-power-production-increased-more-than-coal-power-did-for-first-time-ever-in-2012/?mobile=nc
[122] Ibid.
[123] The China Environment Forum staff will continue to introduce PRCEE researchers with U.S. water-energy modelers to help them in this effort to incorporate water into their co-control analyses. In May 2013 CEF will bring some water-energy experts to China to continue this dialogue.

The PRCEE co-control project reflects the need in the PRC for municipal leaders and utility executives can and must factor water use and stress into decisions about new and existing power plants. The critical switch will be for executives and regulators making energy decisions with long-lived consequences for freshwater supplies to take that charge seriously.

Figure 4: Urumqi and Qingdao Statistics, 2000-2011



White Paper - Appendix 1

Interview Questions & Data Sheets

Energy/Water/Pollution Control Officials and Researchers in Qingdao and Urumqi

Circle of Blue prepared a comprehensive list of questions to apply to its data gathering in Urumqi and Qingdao, and to guide its interviews. The comprehensive list proved valuable in amassing the facts that support this report's findings and results. Broad measures of coal consumption, for instance, were readily available in Urumqi and Qingdao.

The list also served as a means for making the process of fact gathering in Urumqi and Qingdao consistent.

The comprehensive list of questions, prepared prior to departing for the PRC, was meant to serve as a research tool. Circle of Blue's experience in the field found that many of the answers to the detailed questions (coal consumption by specific industrial sectors, for example) were elusive. Other sample questions, like land disturbance in producing coal for both cities, turned out to be low priorities for fact gathering.

A. Gather information regarding the substantive efforts sites have undertaken to reduce their dependence on coal.
A.1. What was total annual coal consumption for both cities each year from 1995 to 2011?
A.2. What was total annual coal consumption for the following sectors in each city from 1995 to 2011:
A.2.a. Heavy industry - cement-making, steelmaking
A.2.b. Utilities
A.2.c. Household heating and cooking
A.3. What was the peak year for coal consumption for both cities from 1995 to 2011 and what was driving the peak in consumption (growth in industry, change in coal pricing, increase in coal supplies, etc.?)
A.4. What was the peak year for coal consumption for the following sectors from 1995 to 2011? *(List year and input from interviewees on factors that led to the peak.)*
A.4.a. Heavy industry - cement-making, steelmaking
A.4.b. Utilities
A.4.c. Household heating and cooking
B. Gather information regarding the environmental impacts of the coal supply chain that provides energy to sites.
B.1. Where are the sources of coal for both cities? *(list mine locations)*
B.2. Based on total coal consumption and use by industry what are the levels in kilograms of toxic air emissions, particulate matter, climate changing emissions, and water consumption (liters) for these sectors in 1995, 2000, 2005, 2010:
B.2.a. Heavy industry - cement-making, steelmaking

B.2, b. Utilities
B.2.c. Household heating and cooking
B.2.d. Transport—trains and trucking
B.3. What are the land use disturbance and water pollution consequences of the coal for the coal supply chain for each city associated with: ***(collect qualitative and quantitative answers for each category below)***
B.3.a. Heavy industry - cement-making, steelmaking
B.3.b. Utilities
B.3.c. Household heating and cooking
B.3.d. Transport—trains and trucking
B.3.e. Coal ash disposal
C. Gather information regarding water use efficiency and water loss (i.e. non-revenue water), extraction and aquifer recharge rates.
C.1. What was total annual surface water consumption in both cities from 1995 to 2011? (include any water transfers, emergency or regular)
C.2. What was total annual groundwater consumption in both cities from 1995 to 2011?
C.3. What was total annual surface water consumption in both cities from 1995 to 2011 in these sectors:
C.3.a. Heavy industry - cement-making, steelmaking
C.3.b. Manufacturing (excluding heavy industry)
C.3.c. Utilities
C.3.d. Municipal uses -- households, small businesses
C.3.e. Agriculture
C.4. What was the total annual groundwater consumption in both cities from 1995 to 2011 in these sectors:
C.4.a. Heavy industry - cement-making, steelmaking
C.4.b. Manufacturing (excluding heavy industry)
C.4.c. Utilities
C.4.d. Municipal uses -- households, small businesses
C.4.e. Agriculture
C.5. What are the major aquifers used by each city? (list names and locations of aquifers)
C.6. What are the groundwater levels in those aquifers in each city in each year from 1995 to 2011?
C.7. What are the recharge rates in those aquifers and what affects recharge?
C.8. How much water is lost during holding and transportation?
C.9. How much water revenue is lost (difference between amount treated and piped versus paid for)?
D. Gather information on current and planned trade-offs between use of water for energy production and other uses, including agriculture.
D.1. To what extent are both cities concerned about use of water for energy production?
D.2. Assuming there is concern, what changes in practice and policy were taken to address the concern?
D.3. Are those policies and practices having any effects on water conservation in the energy sector and in other sectors?
D.4. How are those changes measured?

E. Develop a snapshot (data, charts) of the energy footprint for supplying water to Urumqi and Qingdao.
E.1.Data needed for energy footprint snapshots will be collected in process of answering each of the questions above.
F. Develop a snapshot (data, charts) of the water footprint for supplying energy to Urumqi and Qingdao.
F.1. Data needed for water footprint snapshot will be collected in process of answering each of the questions above.
G. Why do interviewees think that coal peaked in this year (2012) (list factors)
H. Ask interviewee to describe trends shaping water consumption growth in the city
I. Ask interviewee to describe some of the innovative campaigns/regulations that have helped/are helping to promote water conservation

White Paper - Appendix 2

Interviewees

Name	Affiliation	Title	Contact Information
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Piper Stover	China Greentech Initiatve	Director, Strategic Research	piper.stover@greentech.com 10 6460-9388
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Cui Junling	Qingdao Hydrology Bureau	Chief of Engineering	xdhuang@zho3@163.com

Mei Yading	Qingdao Municipal Engineering Design and Research Institute	Water Treatment Engineer	amei8899-gd@sina.com 159-5420-5951
Li Chuambin	Qingdao Huadian Power Plant	Engineer	532-857-73009
Zhang Deliang	Qingdao Huadian Power Plant	Engineer	532-857-73009
Hudian Long	Xinxiang Huadian Power Plant	Assistant Director of Production	hu_dian-long@163.com
Wang Xiufeng	Urumqi Municipal Waste Water Management Bureau	Director, Design and Planning	189-999-06568
Hu Tao	Ministry of Environment, Policy Research Center For Environment and Economy	Chief Economist	hu.tao@vip.163.com

* add +86 for calls from outside PRC

Water and Energy Pollution Nexus in Urumqi and Qingdao

Limiting pollution and securing adequate supplies of energy and water for growing northern and western cities.

Circle of Blue
PRC Policy Research Center for Environment and Economy
Woodrow Wilson Center China Environment Forum

Activity supported by the ADB R-CDTA 6498

The Competition Between Water, Food and Energy

PRC’s demand for energy, particularly for coal, is outpacing its freshwater supply. That, in turn, threatens the productivity of PRC’s farm sector and the economic stability of its fast-growing northern and western cities. The conflicts — “choke points” between energy needs, and demands for food and water — threaten to seriously impede PRC’s economic progress.

Water, Food, Energy “Choke Points” in PRC

- Freshwater needed for mining, processing, and consuming coal accounts for the largest share of industrial water use in PRC, or roughly 120 billion cubic meters a year, a fifth of all the water consumed nationally.

- PRC’s pursuit of larger harvests generates more competition for water with energy producers, and increases risks to erodible land and water quality.

- Over the next decade, according to government projections, PRC’s water consumption, driven in large part by increasing coal-fired power production, may reach 670 billion cubic meters annually — 71 billion cubic meters a year more than three years ago.

- Climate change is disrupting patterns of rain and snowfall.

Co-Control as a Response

“Co-Control”

- A process to identify and implement cost-effective control measures that simultaneously reduce emissions of greenhouse gases and conventional air pollutants in a way that maximizes co-benefits.
- Investigate control targets for air pollutants and deploy various equipment, state-of-the-art industrial practices, and market mechanisms to reduce total greenhouse gas emissions.
- PRC Ministry of Environmental Protection Policy Research Center for Environment and Economy (PRCEE), Beijing Normal University (BNU), and Qingdao University of Science and Technology (QUST).

Co-Control

Co-control prioritizes:

- Applying research, science, and mathematical modeling.

- Clearly defining industrial operating practices and constituents in the waste stream.

- Applying expert manufacturing know-how to understand the price and operating costs of various technologies.

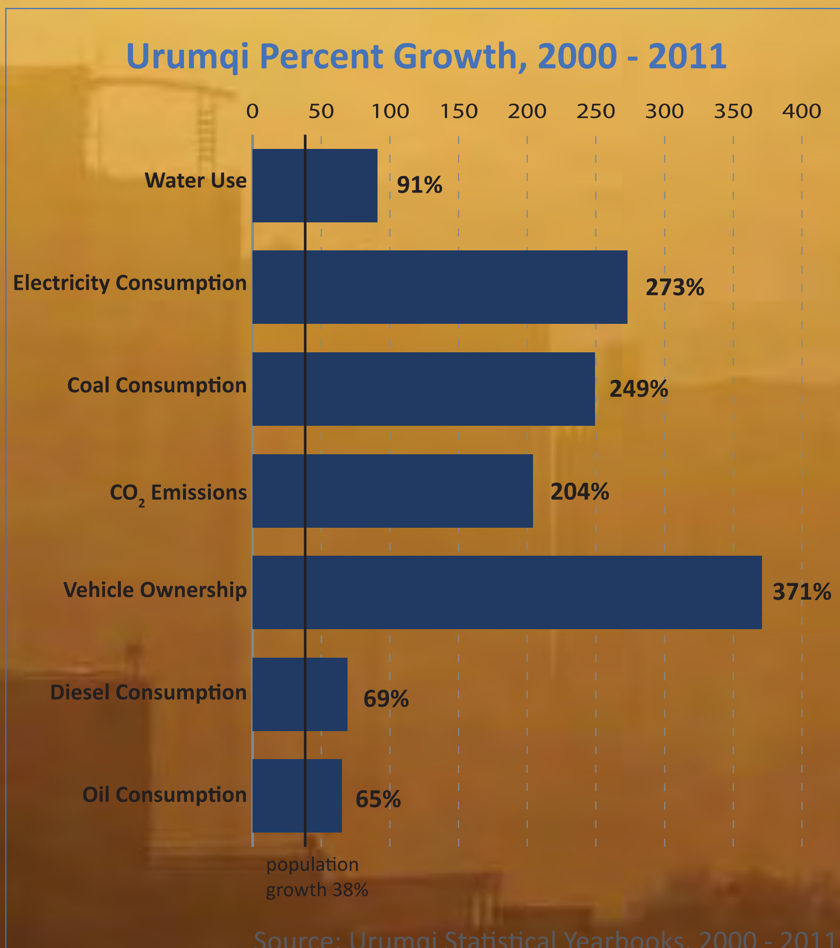
- Choosing the right mix of lower-cost technology and more efficient operating practices to lower costs.

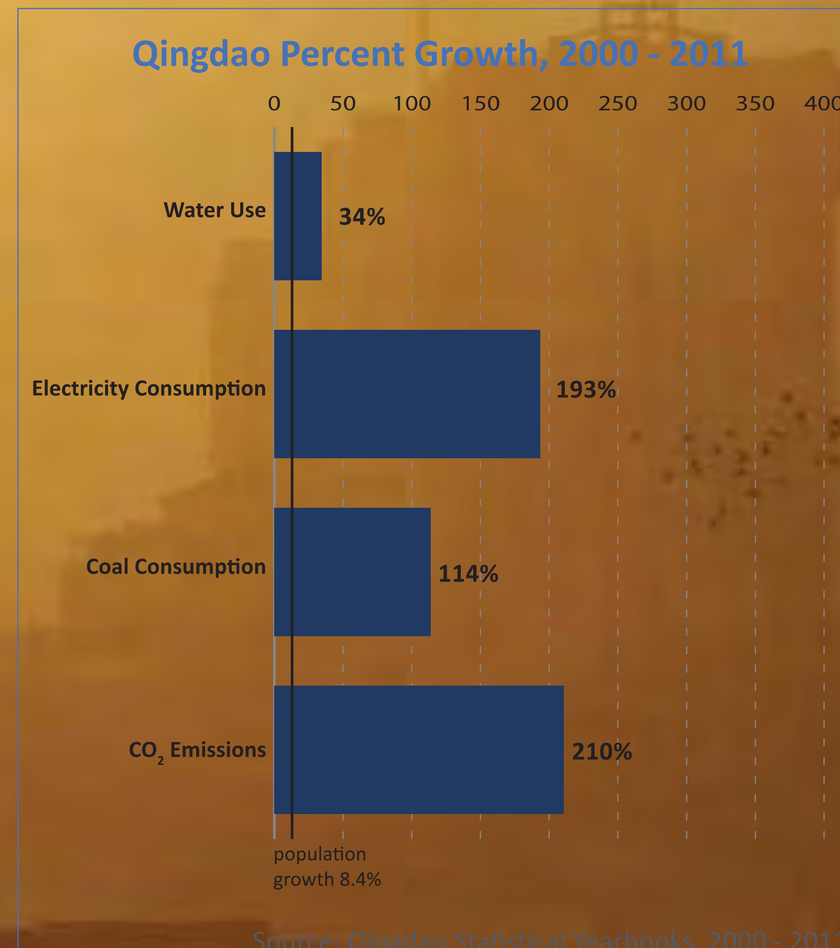
- Compelling industrial operators, through market forces, to comply with China’s tightening environmental standards.

PDA Objectives and Approach

- Understand water, food, energy conflict in two geographically, economically and ecologically distinct cities: **Qingdao** and **Urumqi**
- Develop information for the design of an integrated pollution co-control program in the 13th Five-Year Plan.
- Help design a research agenda to expand MEP's co-control approach to incorporate water.
- Highlight new co-control methodology as an innovation at the city level to manage energy consumption and limit pollution, which offers a model for international engagement to help cities worldwide decrease their energy use, improve air quality, and more efficiently use water.

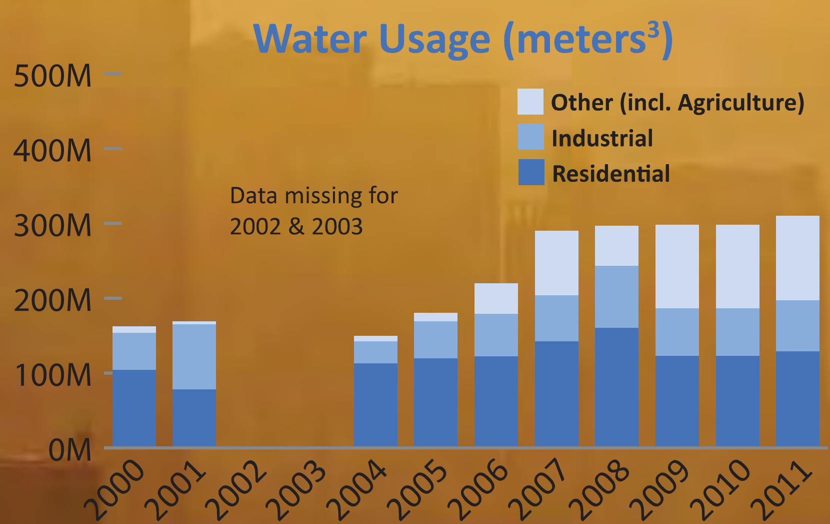
Trends in Two Cities



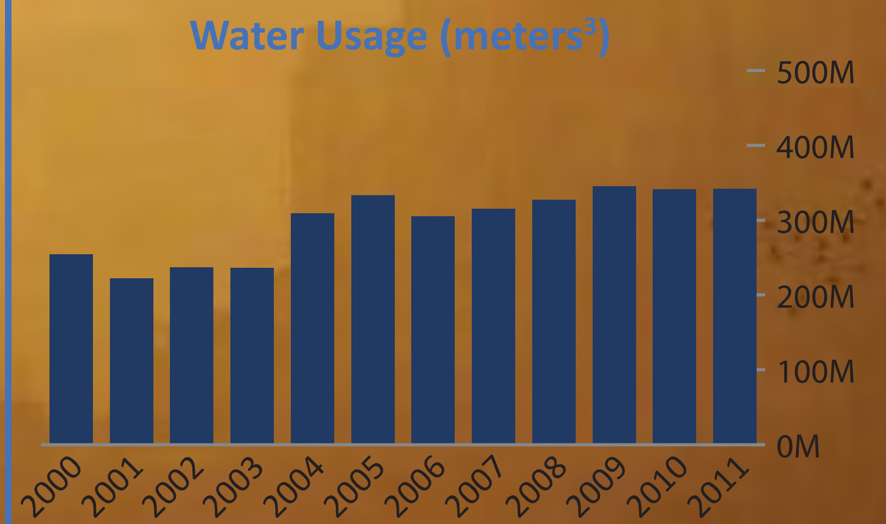


Trends in Two Cities

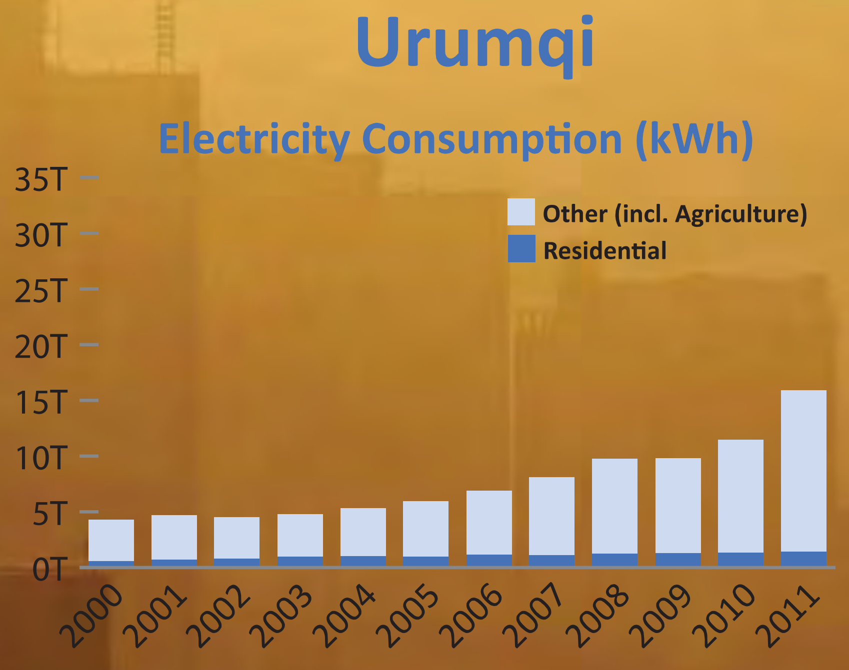
Urumqi

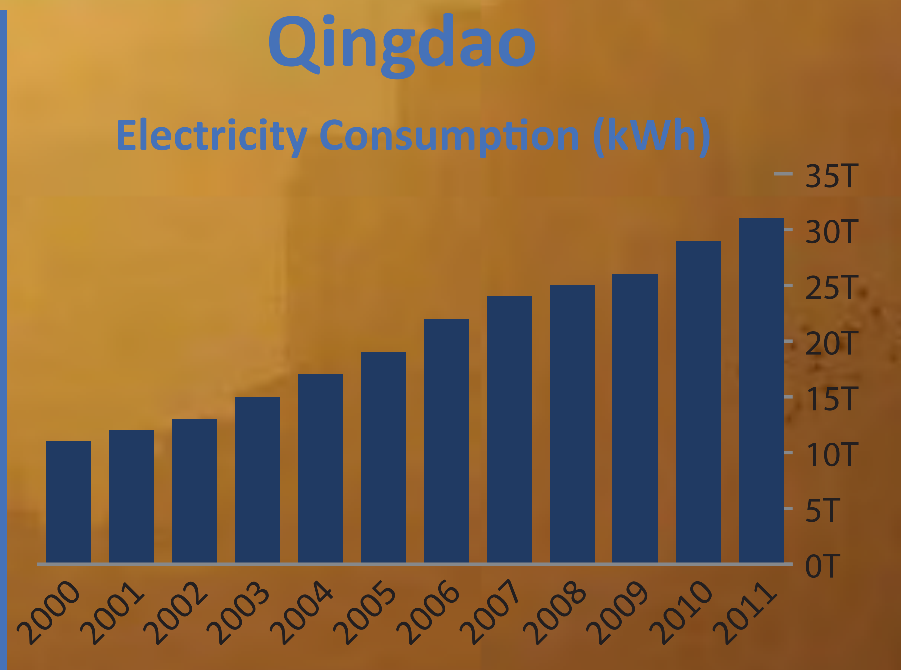


Qingdao



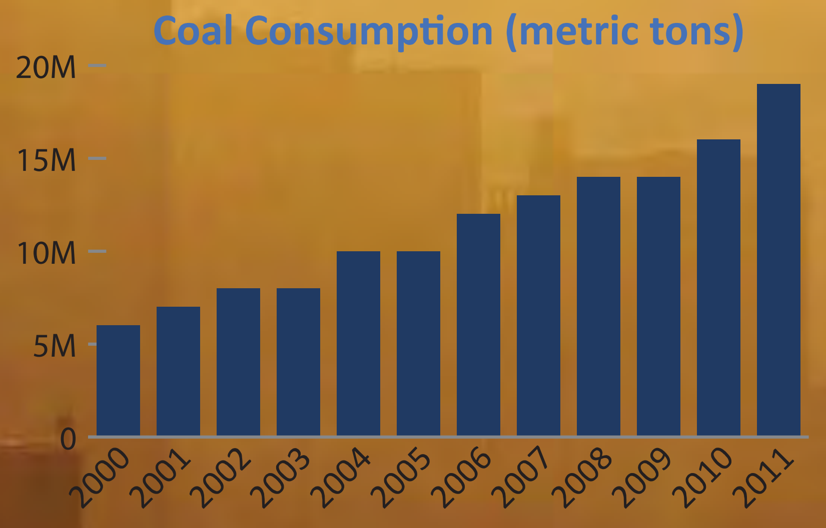
Trends in Two Cities



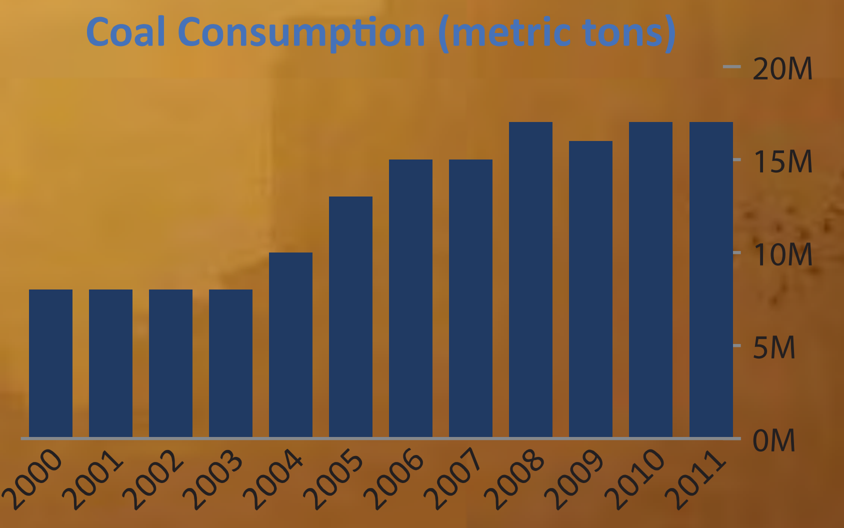


Trends in Two Cities

Urumqi

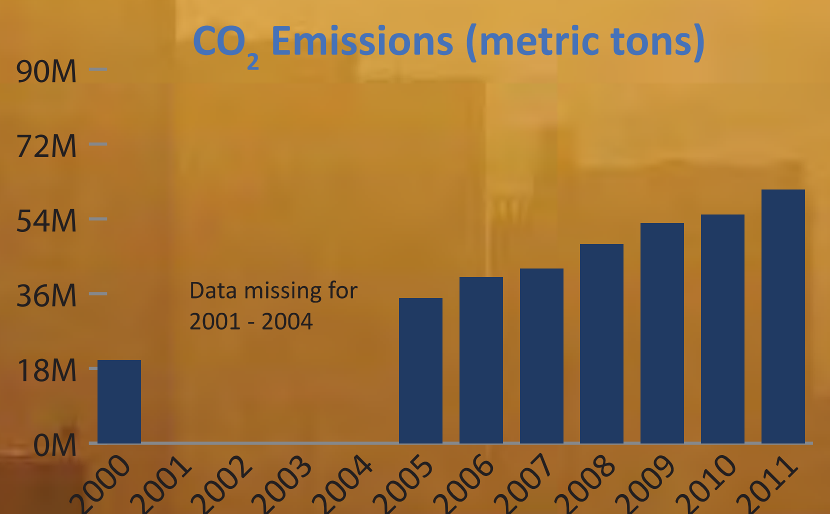


Qingdao

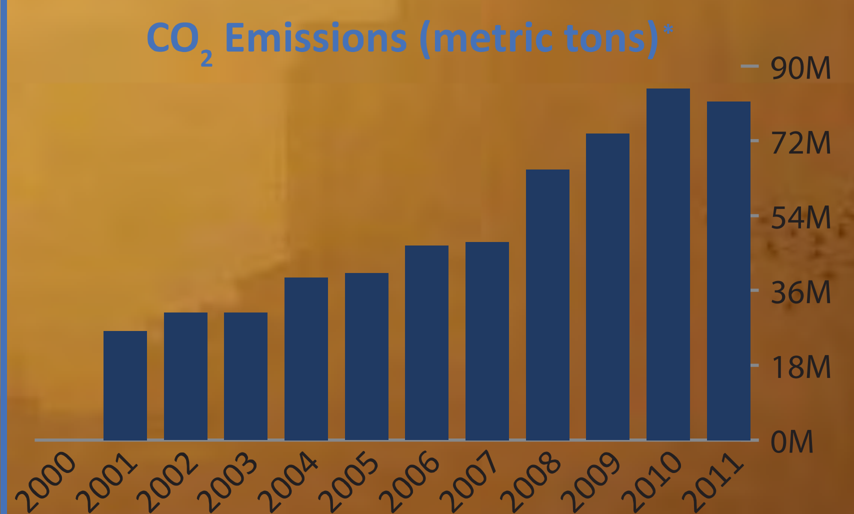


Trends in Two Cities

Urumqi



Qingdao



* Data only for large enterprises. Small and medium enterprises and households not included

NEW APPROACHES NEEDED

Regulation via command and control of single pollutant had limited usefulness

- Conventional command and control approaches in China regulating single pollutants produced unexpected outcomes when it came to controlling primary air pollutants and carbon dioxide.

- Top-down requirements to control sulfur emissions from industrial plants led to the installation of **energy-intensive flue-gas desulfurization** (FGD) equipment to remove SO_2 air emissions.

NEW APPROACHES NEEDED

Regulation via command and control of single pollutant had limited usefulness

- Flue-gas desulfurization consumes large amounts of electricity, generated by coal.
- Every kilogram of sulfur dioxide removed using FGD:
    - Consumed 3.67-kilowatt hours of electricity
    - Used 1.182 kilograms of coal
    - Produced 5.43 kilograms of carbon dioxide
    - Produced .016 kilograms of nitrogen oxide

BOOMERANG EFFECT

FGD is *increasing* China's Carbon Dioxide and other pollutants

- China's wide-spread use of FGD equipment has significantly lowered China's SO_2 Emissions.
- But CO_2 emissions "boomeranged" back because the FGD equipment is energy intensive.

BOOMERANG EFFECT

China's SO_2 Control

- *Increased* electrical power generation by 3,000 to 8,000 megawatts.
- *Increased* the use of coal by 10 million to 28.1 million metric tons annually.
- Produced 45.9 million to 129 million metric tons of carbon dioxide annually.
- *Increased* nitrogen oxide by 135,000 to 381,000 metric tons annually.

NEW MODELS, NEW SOLUTIONS

Putting the Co-Control Model to Work

A cost-effective plan to reduce SOX, NOX, PM 2.5, and carbon at big power plants requires:

- Analysis of efficiency and cleanup capacities of various practices and equipment.
- Calculation of cost of buying and operating the equipment against how much SOX, NOX, and PM 2.5 will be removed from the waste stream.
- Calculation of amount of power needed to operate the equipment and processes.
- Production of a matrix of options from which operators choose pollution reductions.

MEETING AIR QUALITY LIMITS

Co-Control Multi-Pollutant Modeling

- Change coal-washing practices to use less water and less electricity for pumps.

- Modernize boiler ignition systems to use less power.

- Use waste heat to generate steam with ultra high-efficient combined heat and power processes.

- Look for and fix leaks in seals.

- Change boiler systems to incorporate integrated gasification or ultra super critical technologies that produce more power with less coal and less water.

- Substitute smaller boiling units that tend to be more efficient and less expensive to operate.

OPERATING AT SCALE

Potential Improvements from Applying Co-Control Protocol Nationally

Significant reductions in carbon emissions can be attained by intently focusing on reducing **sulfur dioxide** and **nitrogen oxide**.

A 40 percent annual reduction of sulfur dioxide emissions would result in:

- 15 percent reduction in nitrogen oxide.

- 17 percent reduction in carbon dioxide emissions.

TRENDS

Urumqi Air Pollution

Urumqi Air Pollution Trends, Coal Consumption, 2000 – 2011 (Metric Tons)

Year	SOX	NOX	Particulates & Soot	Coal Consumption
2000	73,859	68,000	56,921	5,556,851
2001	86,030	80,000	63,595	6,930,167
2002	92,056	87,000	57,609	7,819,579
2003	99,872	95,000	58,428	8,358,327
2004	109,062	103,000	57,467	9,579,490
2005	121,829	116,000	63,314	10,470,236
2006	133,707	130,000	68,237	11,506,316
2007	142,478	139,000	73,098	12,582,328
2008	137,906	144,000	69,345	13,880,012
2009	133,914	156,000	66,527	13,852,181
2010	132,201	169,000	68,217	15,693,697
2011	137,011	178,000	69,688	19,408,154

Source: Urumqi Statistical Yearbooks, 2000 – 2012; PRCEE statistical data

TRENDS

Qingdao Air Pollution

Qingdao Air Pollution Trends, Coal Consumption, 2000 – 2011 (Metric Tons)

Year	SOX	Particulates & Soot	Coal Consumption
2000	137,643	45,579	7,763,000
2001	126,937	43,741	7,931,000
2002	126,291	42,459	8,166,000
2003	130,156	38,292	8,338,260
2004	151,664	51,767	9,960,515
2005	155,351	53,457	13,042,275
2006	146,537	47,110	14,890,737
2007	122,884	38,378	15,213,503
2008	114,208	38,601	16,626,322
2009	113,625	36,556	15,927,802
2010	103,451	45,987	17,499,668
2011	102,807	42,390	16,604,994

Source: Qingdao Statistical Yearbooks, 2000 - 2012

REDUCING EMISSIONS

Potential Improvements from Applying Co-Control Protocol Nationally

Significant reductions in carbon emissions by intently focusing on reducing sulfur dioxide and nitrogen oxide, translate into:

- 12.4 million metric tons of sulfur dioxide
- 7.9 million metric tons of nitrogen oxide
- 1.15 billion metric tons of carbon dioxide

…not released into the atmosphere.

PDA Findings: Water

Urumqi and **Qingdao** are fast-growing cities with critical water shortages. Water scarcity is increasing due to multiple causes, including increased demand, inefficient use, and climate change. The number of residents and industrial plants is growing steadily in both cities.

- Rising energy production demands more water.

- Energy demand for treating and delivering water is rising.

- Water should be included as a key point of research and reference for the PRCEE co-control methodology.

Energy for Water: Urumqi

Urumqi's demand for energy and water, wastewater treatment, and recycled water is soaring:

- Treating 310 million cubic meters of drinking water daily, roughly twice as much as in 2000. Demand is expected to grow to 600 million cubic meters by 2015.
- Cleaning up 200 million cubic meters of wastewater daily.
- Recycling 150 million cubic meters of wastewater daily for use in industrial operations.

Energy for Water: Urumqi

Urumqi's demand for energy and water, wastewater treatment, and recycled water is soaring:

•1.5 billion kilowatt hours of electricity is needed to treat **water**

•More than the 1.39 billion kilowatt hours of electricity were used by Urumqi' s residents in 2011.

•This is the same amount of power generated by a 300-megawatt coal-fired generating station* that consumes 1 million tons of coal.

** producing tens of thousands of pounds of sulfur, nitrogen oxide, and particulates annually and 2 million metric tons of carbon dioxide.*

Water for Energy: Urumqi & Qingdao

Coal is the primary energy source for Urumqi and Qingdao.

Urumqi

22 million tons burned per year, 19.4 million tons for power and industry.

Qingdao

16.6 million tons in 2011, doubled since 2000.

Water Pressures: Urumqi & Qingdao

Increasing demand is causing water shortages. Now.

- Industrial plants and population are increasing steadily
- Urumqi's population, now ~3 million, has nearly doubled since 2000
- Qingdao's population, now ~8million, is growing by nearly 80,000 people per year.
- Increase in water-thirsty industrial, manufacturing and power plants has increased demand for water in both cities.
- Sharp increase in demand for electricity has increased demand for coal; the coal sector, at all levels, needs water.

Water Pressures: Urumqi

Declining supplies are causing water shortages. Now.

- In Urumqi, 43% of water supply is from aquifers that are dropping.
- Remaining 57% is surface water collected in reservoirs near the city.
- Both aquifer and surface supplies come from snowmelt and the Tianshan Mountain glacier.
- Due to climate change, the glacier is receding and the snow line is retreating to higher elevations.

Discussion: Forward

The electricity required to transport and treat water in China's growing cities is a vital area of research. So is the growing contest for China's fresh water reserves – which are declining most dramatically in China's dry north.

Climate variability and the need to reduce GHG emissions could lead to a dynamic, sector-wide transition in electrical supply that more readily fits the conditions that China faces.

Discussion: Forward

Critical decisions for utilities and government regulators:

- Location and construction of new generating systems.
- Determining fuel choices.
- Assessing power demands.
- As confrontations over water become more numerous, ensuring that power plants and other sectors have adequate supplies.
- By considering the effects of water use in the co-control methodology, executives and regulators can develop a much more precise understanding of how choices of generating technology in the next decade will set the country on very different water paths.

Discussion: Consequences

Making the wrong choices in electricity supply technologies and fuels could have significant negative impacts.

Energy demand and water supply is uneven around China. The north and northwest, two of the fastest growing regions, as well as China's central coast, are imperiled by long-term drying conditions.

Unless utilities and government planners carefully evaluate the new hydrological trends and make incisive choices for water-conserving generating technology and fuels, the economies, quality of life, and environment in these regions could lead to environmental degradation.

Discussion: A Co-Control Future

An electrical supply system that conserves water should be achievable, could dramatically reduce climate-changing emissions, and lower operating costs and prices for electricity.

- Co-control methodology can help energy planners and regulators anticipate and plan for potential shortages of water, and adjust the size, location, technology and fuel of energy generation projects.
- Because moving and treating water requires considerable amounts of electricity, reducing water consumption should reduce primary air pollutants.
- By considering the effects of water use in the co-control methodology, executives and regulators can develop a much more precise understanding of how choices of generating technology in the next decade will set the country on very different water paths.

Choosing a sound water supply strategy for supplying China with electricity is crucial for sustainable development.

PRCEE Co-Control

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Activity supported by the ADB R-CDTA 6498