

Environmental Aspects of Electricity Grid Interconnection in Northeast Asia

David Streets

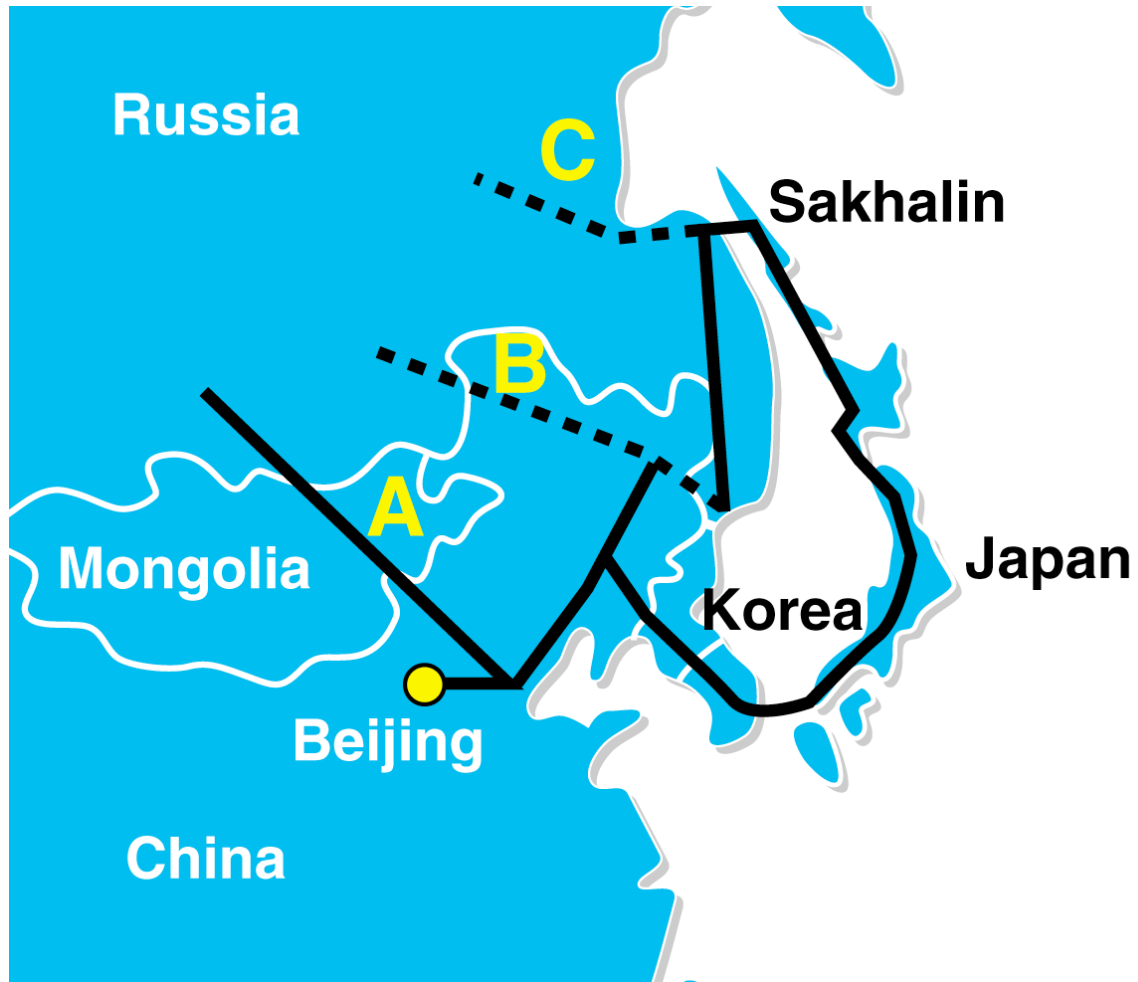
Argonne National Laboratory

Workshop on Power Grid Interconnection
in Northeast Asia

Beijing, China

May 14-16, 2001

Potential Power Grid Interconnections in Northeast Asia



Developments in Power Sector Energy Use (PJ)

	<u>Year 2000</u>			<u>Year 2020</u>		
	<u>coal</u>	<u>oil</u>	<u>gas</u>	<u>coal</u>	<u>oil</u>	<u>gas</u>
NE Plains/PRC	1505	189	18	2347	110	140
DPRK	199	0	0	480	0	0
ROK	752	362	230	1237	339	730
Japan	1784	1703	1757	3161	1271	1281

Environmental Benefits of Increased Grid Interconnection

- **Reduced emissions of local air pollutants**
- **Reduced human exposure to ambient pollution, due to the separation of source and end-use**
- **Potential reductions in long-range pollutant transport and regional problems like acid rain, ozone, etc.**
- **Potential reductions in greenhouse-gas emissions**
- **Reduced coal mining and coal transportation**
- **Opportunity to displace biofuel combustion in rural areas**
- **Opportunity to enhance the use of renewable energy, such as hydroelectricity**
- **Encouragement of harmonized environmental regulations**

Potential Environmental Dis-benefits

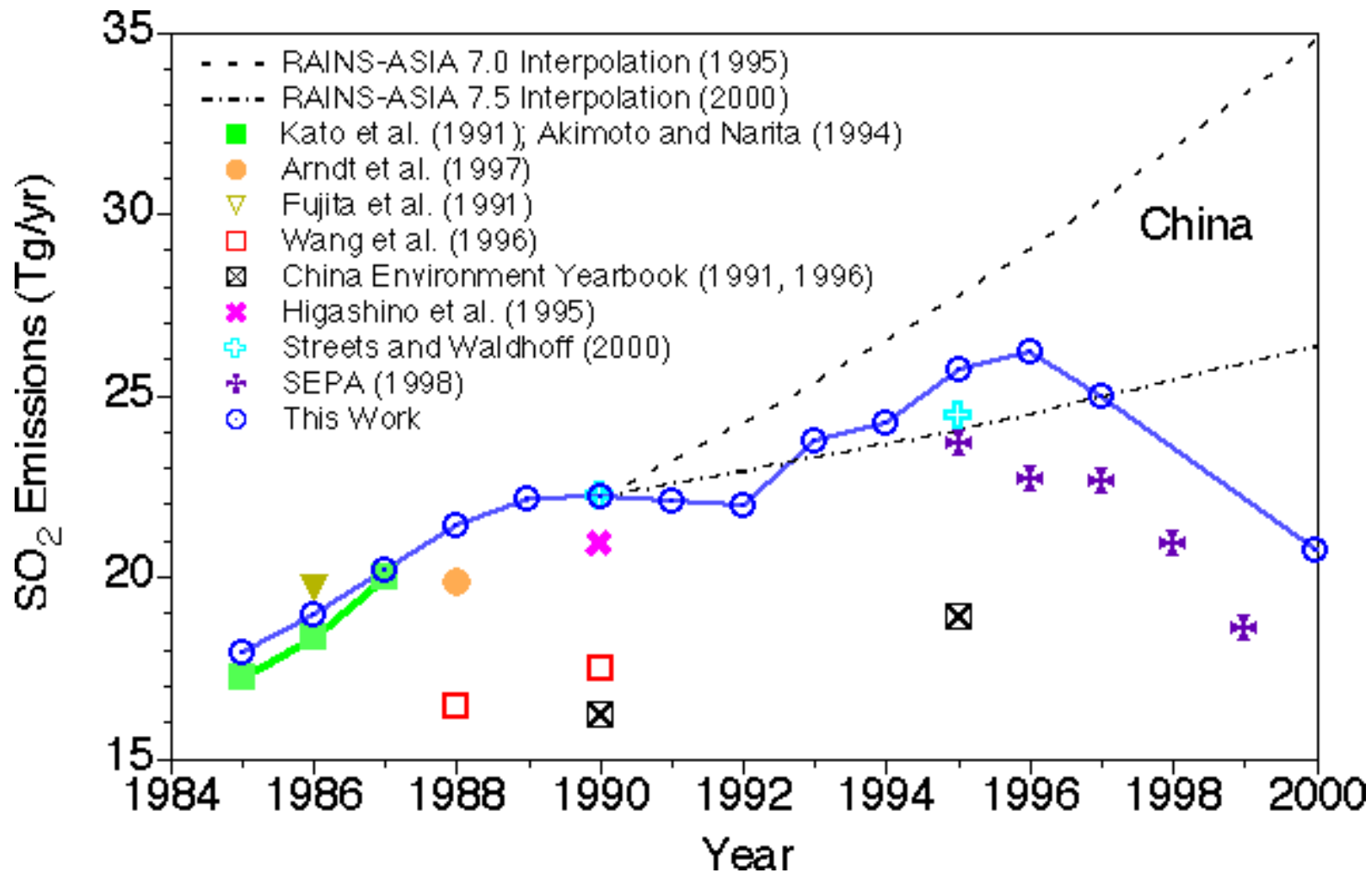
- **Increased combustion emissions at point of electricity generation**
- **Increased methane emissions from natural gas extraction, processing, and distribution**
- **Possible marine ecosystem damage from offshore gas extraction and undersea cables**
- **Possible human health and ecosystem effects from transmission lines**
- **Environmental effects of alternative energy sources (nuclear, hydro, wind...)**

There Has Been a Remarkable Change in Air Pollution Emissions in China Since 1995, Due to:

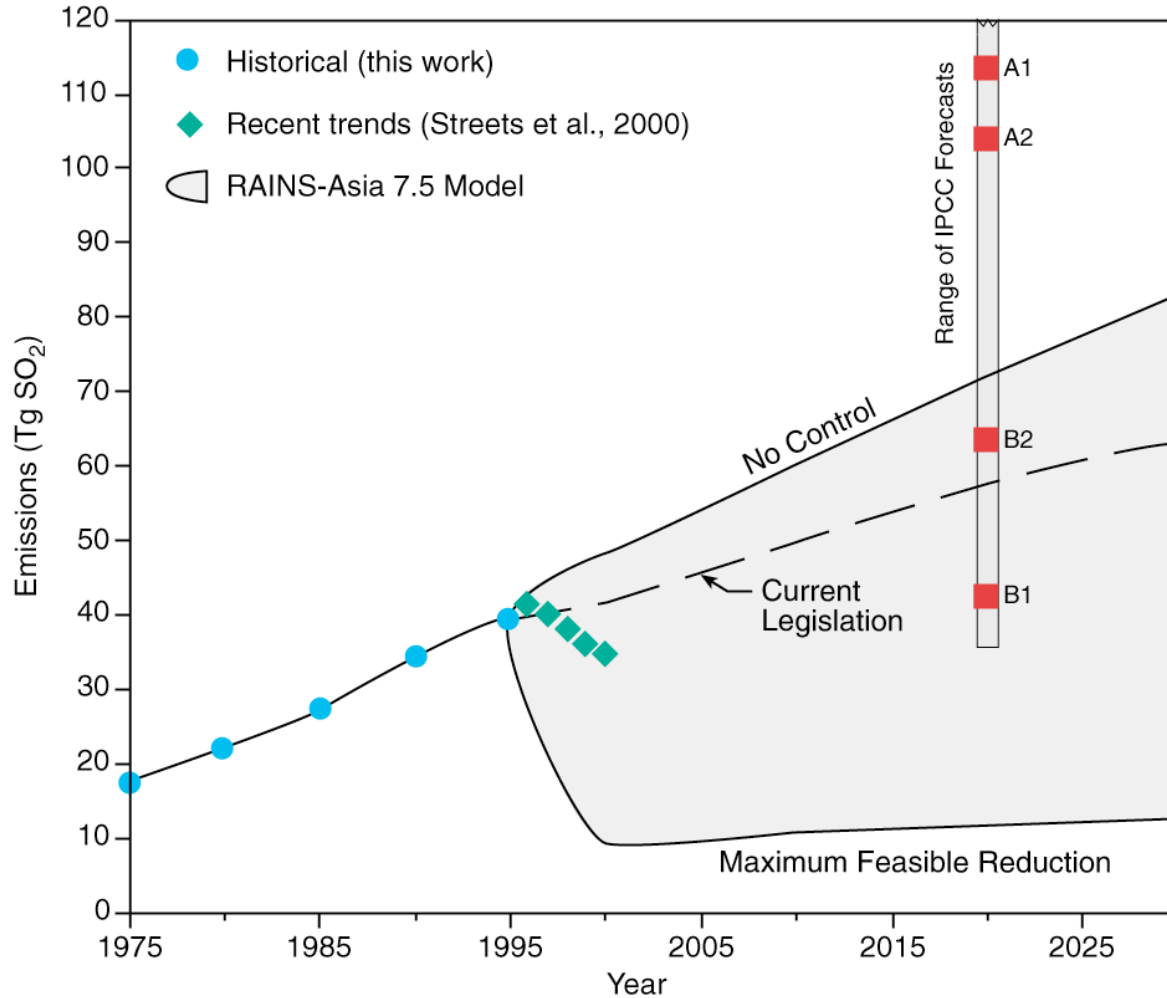
- **The economic downturn in 1997-98 in East and Southeast Asia**
- **Reform of industry and power, leading to a reduction in coal use**
- **Structural shift away from heavy industry towards high-tech industries and services**
- **Improvements in energy efficiency and fuel quality**
- **Closing of many small, inefficient, high-sulfur coal mines, reducing the over-supply of coal**
- **Slowdown in electricity demand, due to higher electricity prices**
- **Opening up of power and industrial markets**
- **Residential fuel switching from coal to electricity and gas in (large) cities**

Question: *Are recent energy-use reductions overstated??*

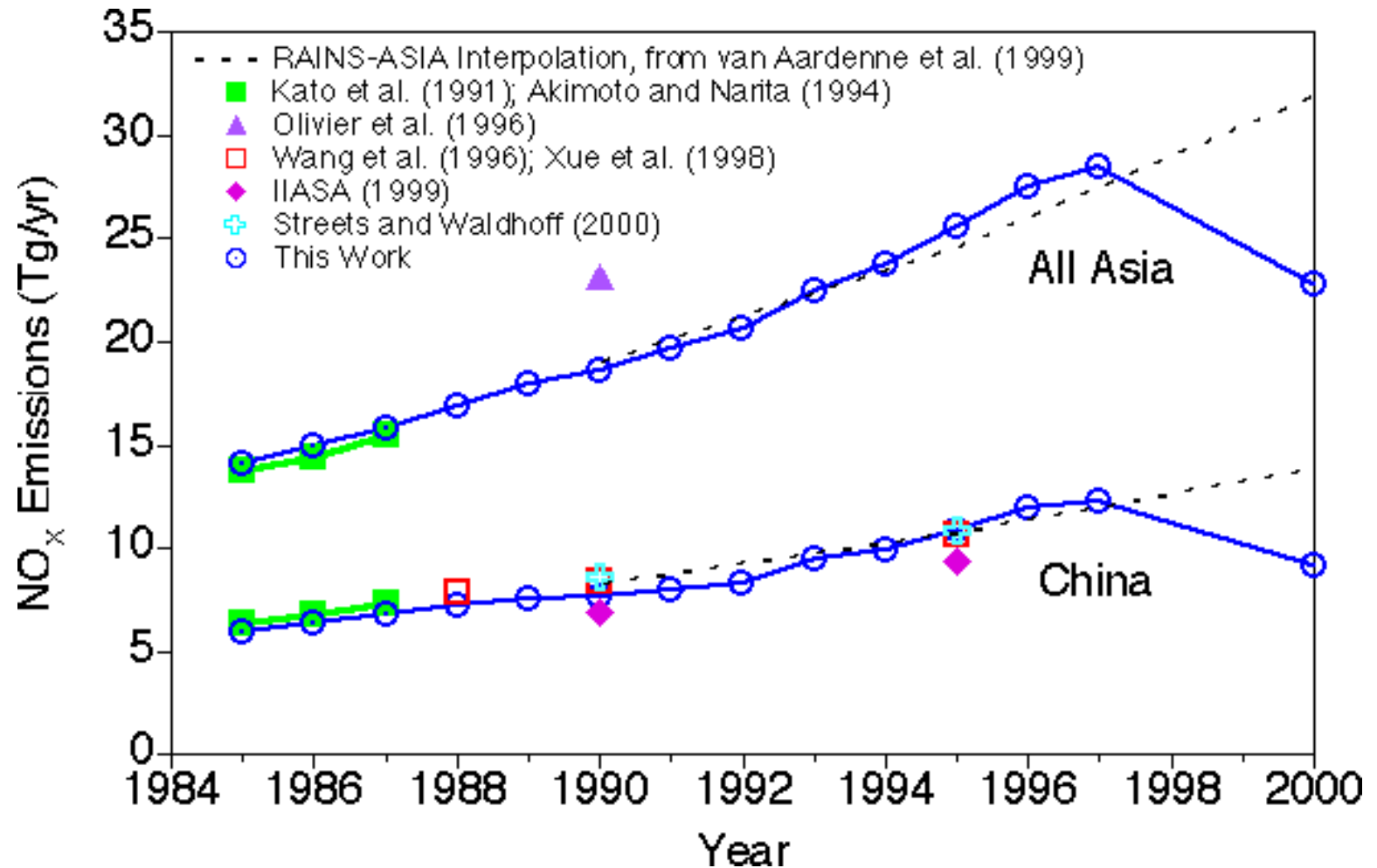
Recent SO₂ Emission Trends in China



Future SO₂ Emissions in Asia



Recent NO_x Emissions Trends



Electricity Generation in Northern China in 1999 (TWh)

Beijing	14.3	Tianjin	18.1
Nei Mongol	38.1	Liaoning	61.0
Jilin	30.0	Heilongjiang	41.2
Northern China	202.7 (16.4%)		
All China	1239.3		

According to APERC, potential electricity supply from:

Irkutsk	15 (by 2005-2010)
Irkutsk + Chita	25-30 (by 2005-2010)
Irkutsk + Chita + Yakutia	40-50 (beyond 2010)

Typical Emission Factors (Gg/PJ) from Power Generation

	SO ₂	SO ₂ *	NO _x	CO	BC**	CO ₂
coal	0.61	0.06	0.30	0.02	0.00001	96
oil	0.26	0.07	0.20	0.02	0.008	77
gas	0.01	0.01	0.15	0.03	0	56
[coal]	0.51	0.07	0.08	3.5	0.18	96
[biofuel]	0.06	0.06	0.05	5.1	0.07	110

*with controls, such as FGD for coal, low-sulfur oil, briquettes, etc.

**black carbon, i.e., sub-micron elemental carbon

[...] = residential fuel use

Local Air Quality Benefits

- Existing power plants are co-located with urban centers, are largely coal-fired, and typically only have electrostatic precipitators for control of particulate matter (no S control)
- They are a major source of SO₂ and PM, and a significant source of NO_x
- Thus, they contribute to the high ambient levels of pollution in northern Chinese cities, which impair human health, largely through inhalable PM (primary particles and sulfate, though ambient SO₂ is a health danger in some cities)
- Displacement of existing and/or planned coal-fired power plants with imported electricity would contribute to air-quality improvement and reduction in health damage
- In Shanghai, we have estimated benefit/cost ratios of 1-4 for control of SO₂ and PM from the power sector (4-12 for the industrial sector)

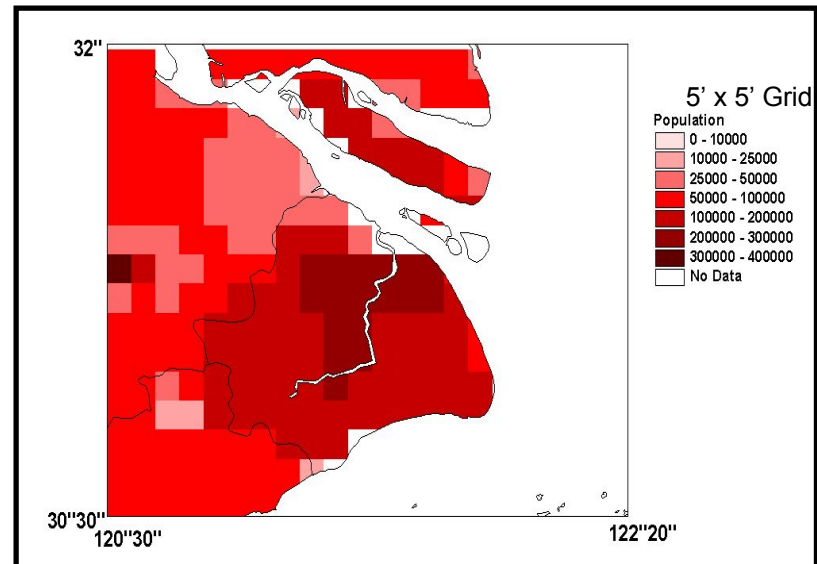
Air Quality in Selected Northern Chinese Cities

Annual Daily Average Concentrations in 1995 (: g/m³)

	NO _x	SO ₂	TSP
Beijing	122	90	377
Changchun	64	21	381
Dalian	100	61	185
Harbin	30	23	359
Lanzhou	104	102	732
Shenyang	73	99	374
Shijiazhuang	61	129	308
Taiyuan	55	211	568
Tianjin	50	82	306
WHO Guidelines	150	100-150	150-230

Change in Mortality due to PM Control in Shanghai

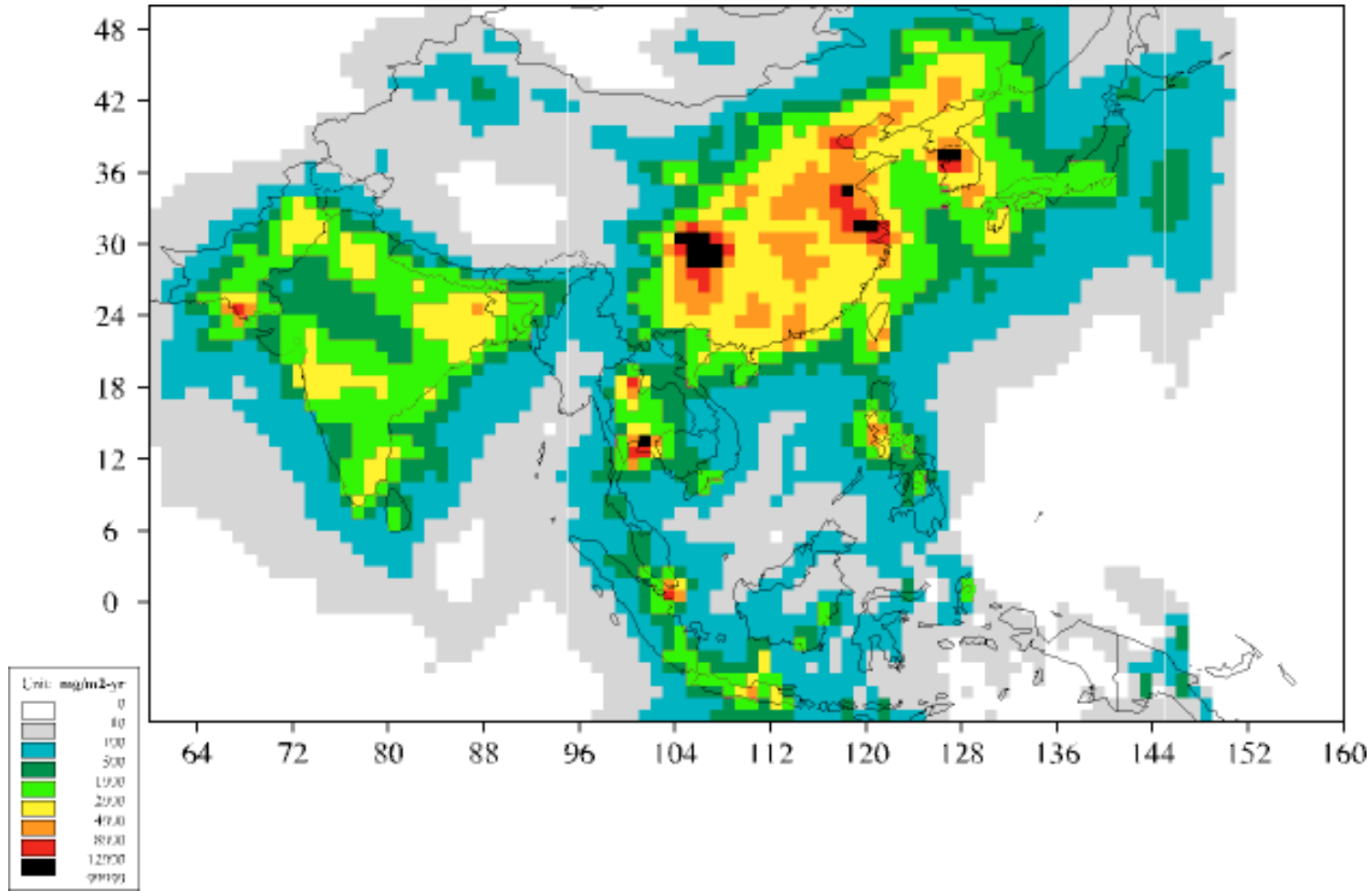
Year 2020	Power Sector	Industrial Sector
Emission Reduction (%)		
SO ₂	41	14
NO _x	13	6
TSP	3	9
PM ₁₀	4	12
PM _{2.5}	4	13
Benefits (\$ millions)		
Mortality	257	188
Morbidity	148	108
Costs (\$ millions)		
	395	94
Health Benefits/Costs Ratio		
	1.03	3.15



Regional Air Pollution Issues

- **Long-range transport: Northern China → Korea → Japan → North America (?!)**
- **Regional visibility impairment, reduced insolation--compounded by dust from western deserts**
- **Acid rain, sulfur deposition, nitrogen deposition (NH_3 involvement from fertilizer use), eutrophication of surface waters**
- **Regional ozone formation, caused by organics + NO_x with the involvement of CO and CH_4**
- **Trace elements from coal combustion, particularly Hg**

Without Additional Control Measures, Deposition Levels Will Cause Widespread Damage by the Year 2020



Regional Sulfur Source-Receptor Relationships

Receptor/Source	NEP	Jiangsu	Japan	DPRK	ROK
Shenyang, PRC	66	1	0	1	1
Beijing, PRC	0	1	0	0	0
Tokyo, Japan	2	2	78	1	9
Pyongyang, DPRK	17	3	0	29	37
Seoul, ROK	4	3	0	2	84

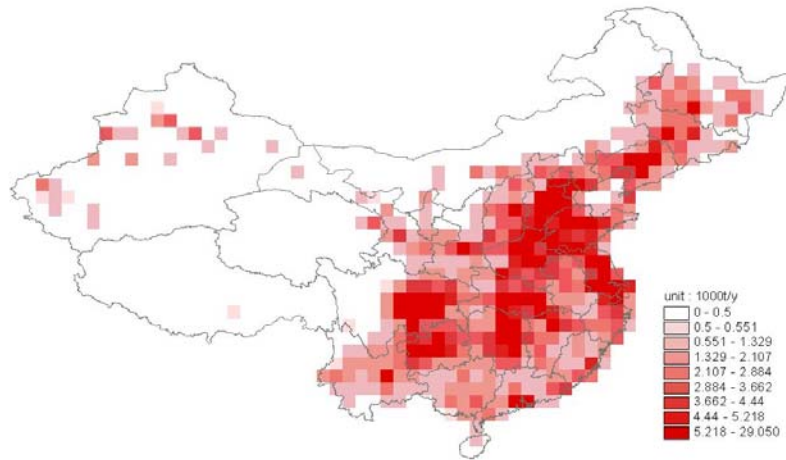
Combustion Devices in Xian, China



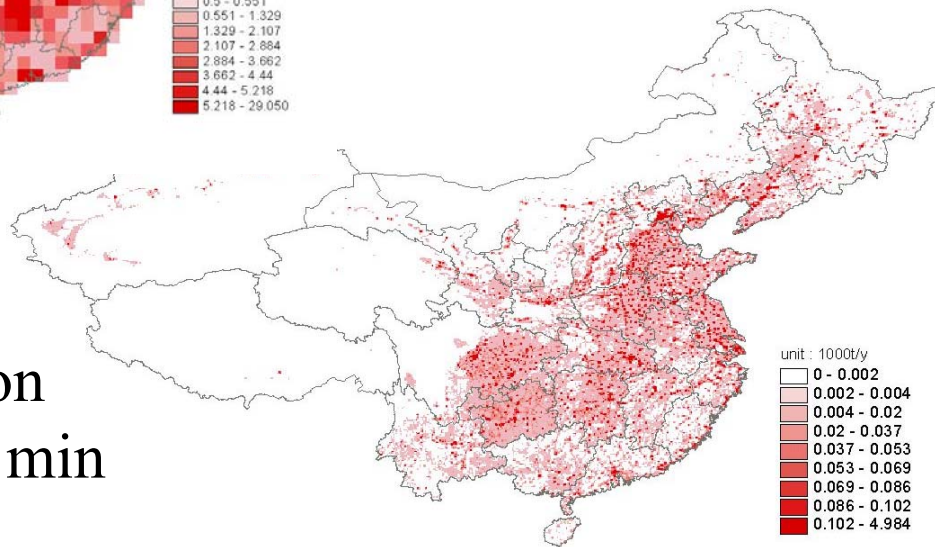
Photos courtesy of Beverly Anderson

Black Carbon Emissions in China

Gridded Black Carbon Emissions at 1 deg x 1 deg resolution



Gridded Black Carbon Emissions at 5 min x 5 min resolution



Global Issues

- **Potentially reduced emissions of greenhouse gases (CO₂ mainly)**
- **Reduction depends on the technology and fuel used to generate the electricity at the source**
- **Emissions of CH₄ could increase if natural gas is the source (from extraction, processing, and distribution)**
- **Issues related to the Kyoto Protocol (Japan required to reduce emissions by 6% from 1990 levels; China not a party to the agreement)**
- **Recent ghg emission trends in China have broad implications**

Conclusion: Regional Grid Interconnections are Likely to Provide Net Environmental Benefits

- **Local benefits to human health in some northern Chinese cities could be significant; also possible for DPRK and ROK**
- **Health benefits at point of electricity use are likely to outweigh ecosystem dis-benefits at point of electricity generation**
- **Regional air-quality benefits are likely to be positive but small**
- **Global benefits are likely to be positive but very small; Japan could benefit**
- **Social benefits to northern China and DPRK will be significant**
- **Amount of electricity likely to be available is relatively small to have a really large effect**