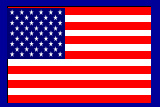
The US Experience
Controlling SO_2 Emissions
In the Power Sector
电力部门控制二氧化硫排放的美国经验

Clean Air Initiative - Asia
Urumqi, China 2006

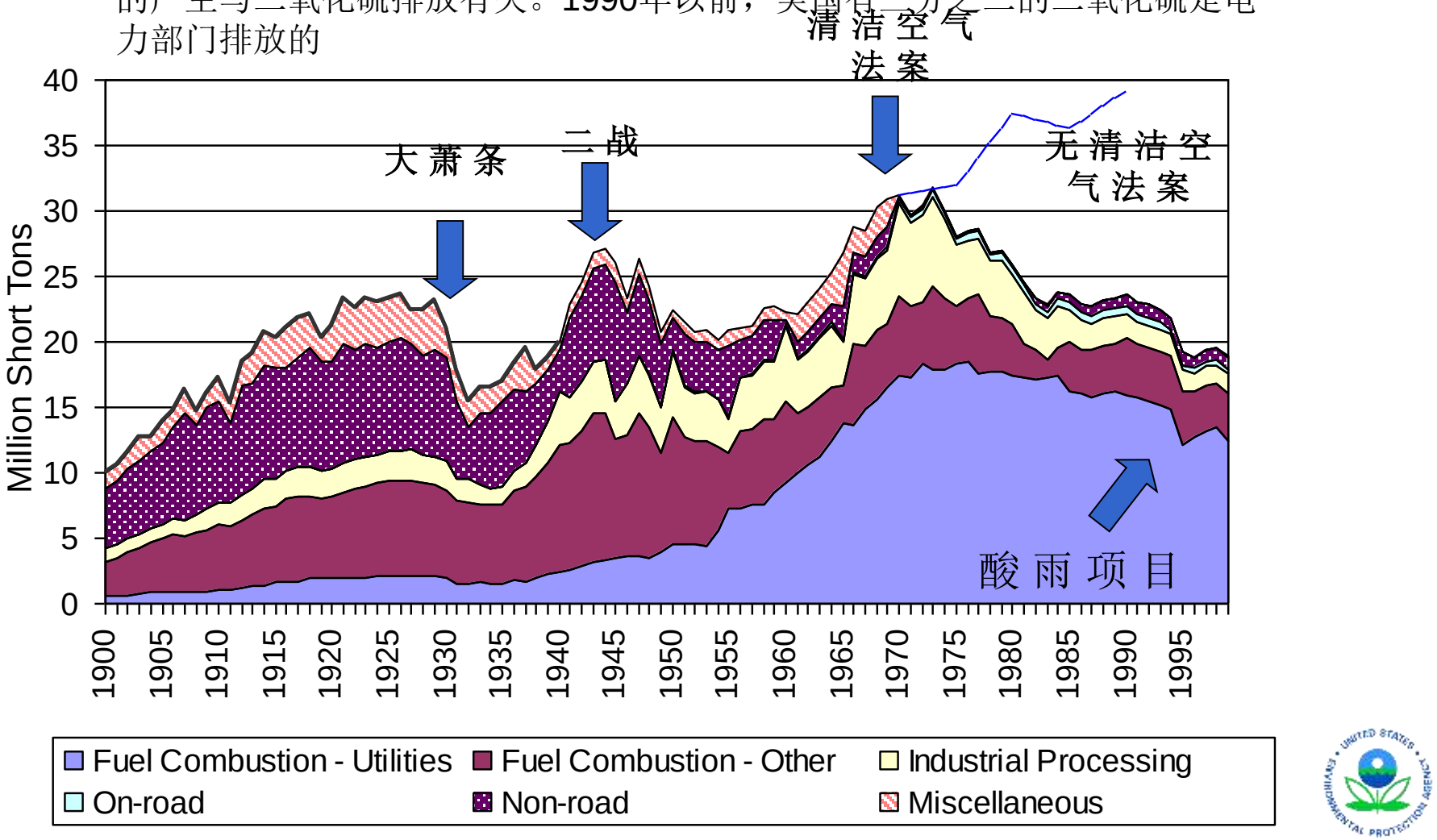
Peter H. Kokopeli
U.S. Environmental Protection Agency
Clean Air Markets Division

History 历史

- In the 1970s, the environmental, social, and economic effects of acid rain in the United States became a major concern to policy makers and the public. This resulted in passage of the Clean Air Act of 1970 and subsequent amendments in 1977 and 1990.
- 上世纪七十年代，酸雨在美国的环境、社会和经济影响已经成为政策制订者和民众的主要关注对象。这导致了1970年“清洁空气法案”的通过及其1977年和1990年的修订。

美国二氧化硫排放历史

- Researchers linked acid rain to SO_2 emissions. By 1990, two thirds of SO_2 emissions in the US were from the power sector ('Utilities') 科学家认为酸雨的产生与二氧化硫排放有关。1990年以前，美国有三分之二的二氧化硫是电力部门排放的



Three US Approaches to Controlling SO_2 Emissions
美国控制二氧化硫排放的主要措施

Standards-based 标准限制

- NAAQS (National Ambient Air Quality Standards) define attainment and protect human health by setting a limit on SO2 concentration nationwide. New and modified sources must meet technology and performance standards designed to prevent any significant deterioration of air quality. These standards set maximum emission levels and may specify BACT – 'Best Available Control Technology' for new units. 国家环境空气质量标准规定了全国的二氧化硫浓度限值来保护人民健康。新建和改建的污染源必须满足设计的技术和性能标准来防止空气质量的恶化。这些标准设定了最大排放水平，还可能指定新设备要使用的“最佳可用控制技术”。

Voluntary programs 自愿的项目

- Government agencies working with industry to establish 政府和工业部门合作建立
  - Demand Side Management programs, to encourage consumers to reduce usage during periods of peak demand. Electric utilities are extending time-of-use metering with three different price levels (on-peak, off-peak and intermediate) from commercial customers to residential. 'Smart meters' display actual cost to the user. 需求方管理项目，来鼓励消费者在需求高峰期减少用量。用电的高峰、低估和中间时期有不同的价格水平。
  - Energy Conservation measures such as more efficient appliances 节能措施如节能设备
  - Renewable energy. U.S. EPA is the first US government agency to purchase 100% renewable. (How much? 300 million kWh per year primarily through the development of wind farms). 可再生能源。美国环保署是第一个购买100％可再生能源的的美国政府机关 （多少？3亿千瓦时每年，主要通过发展风能）

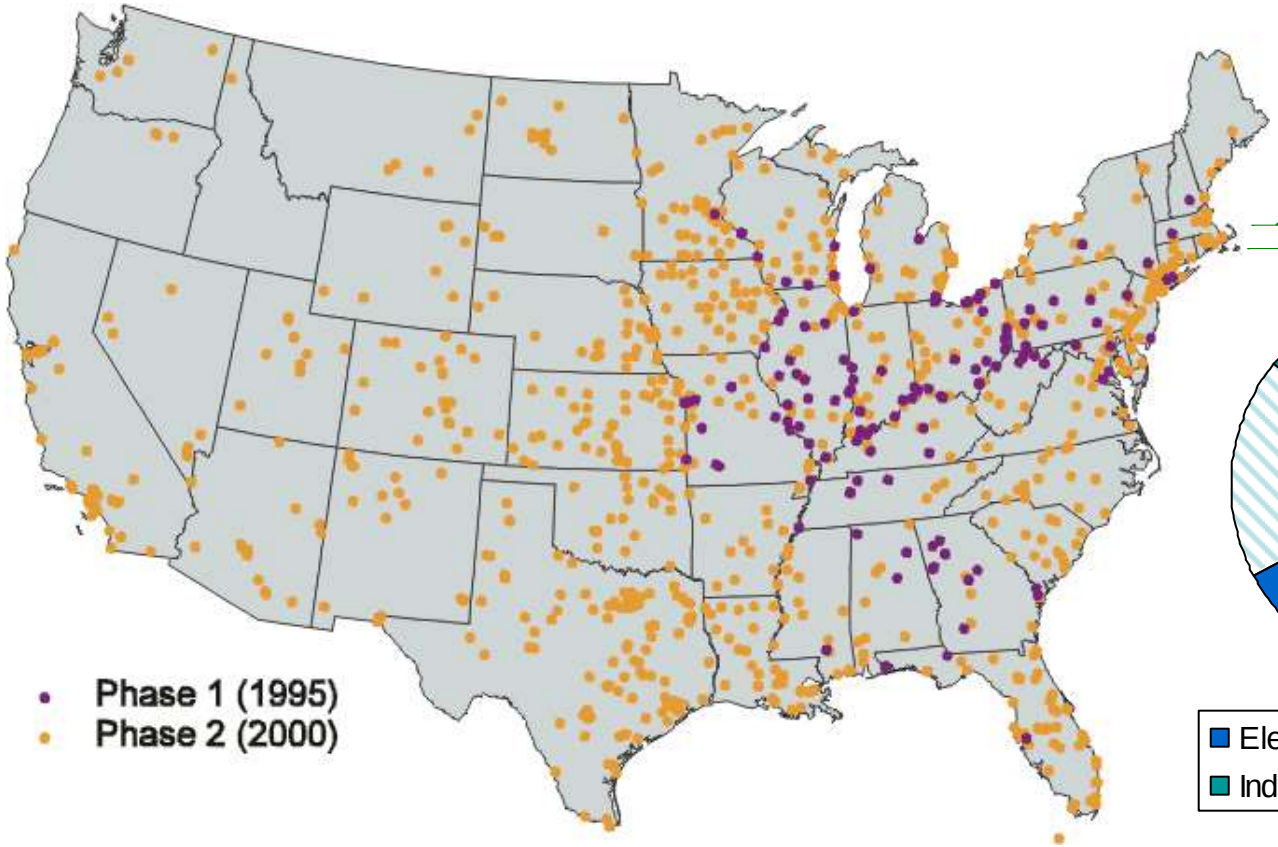
Three US Approaches to Controlling SO_2 Emissions
美国控制二氧化硫排放的主要措施

Cap & Trade 排污交易

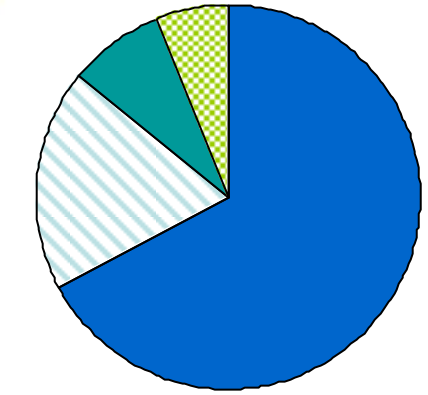
- The Acid Rain Program (ARP) established an absolute cap on SO_2 emissions for affected sources. It is national in scope, and through market-based allowance trading it allows plant operators to select their own compliance strategy. The EPA currently issues 8.95M SO_2 allowances annually. Allowances are a financial asset and may be traded on the market. As such, they provide an incentive for industry to increase efficiency, innovate, and reduce emissions within certain timeframes. The U.S. EPA Clean Air Markets Division (CAMD) operates the ARP Cap & Trade program which is responsible for the bulk of SO2 reductions. 酸雨项目建立了一个所有二氧化硫污染源的排放总量的绝对限值。这是一个国家的总量，通过基于市场的排污交易，不同的企业可以选择自己的达标战略。美国环保署现在每年发放了890万吨的二氧化硫排污配额。排污配额是一种资产，可以在市场上进行交易。这样一来，在一定时间框架下，企业有动力提高他们的效率、创新和减排能力。

- **Although these approaches differ in philosophy and implementation they have been complementary to the goal of lowering emissions. 尽管这些措施的哲学和实施角度不同，他们都是实现减排目标的重要补充。**

分 配 职 责

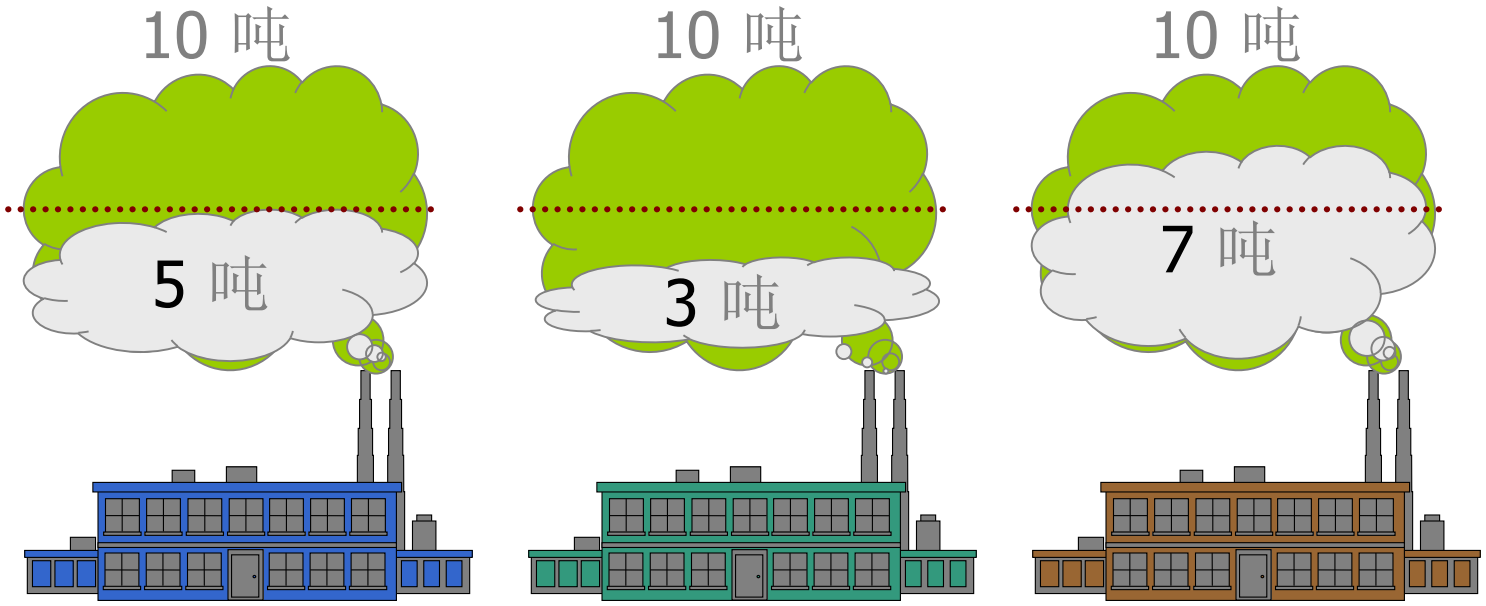


二 氧 化 硫 排 放 1990



- Acid Rain Program (ARP) units in the US now total approximately 3,600. 美国现在约有3600个酸雨项目

限额与交易



蓝色

成本：$200/吨

消减量：5 吨

Green

成本：$160/吨

消减量：7 吨

褐色

成本：$240/吨

消减量：3 吨

以每吨 $160 - $240 转让 2 个配额

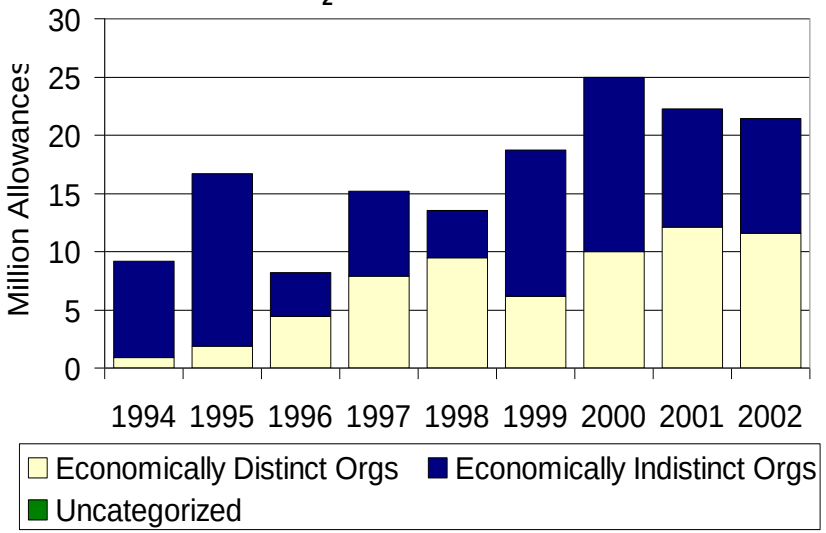
Essentials of Cap & Trade 排污交易的核心内容

- Set a mandatory emissions cap based on sound scientific evidence that the limit will have the desired environmental effect. 足够的科学证据说明限制可以取得预期的环境收益，基于此，设定强制性的排放总量限值
- Establish Cap & Trade as an alternative to traditional regulation — not simply a trading feature added to existing regulation. 排污交易是传统法规的一个补充，不是简单地把交易的特点赋予现有的法规
- Ensure that a significant number of sources will participate sufficient to create a viable allowance market. 保证有足够的污染源参与交易来建立一个有效的排污交易市场
- Allocate allowances in an amount not to exceed the cap. 给各个污染源分配允许的最大污染物排放量
- Mandate that sources must hold allowances to cover annual emissions. 强制污染源必须保留排污配额来冲抵年排放量
- Monitor and verify emissions. All records, including allowance holdings must be publicly available. 对各个源的排放量进行监督，所有记录必须公开
- Enforce rules with automatic penalties.
- Assess results on a consistent basis to evaluate how the program is working over time. 持续评价项目实施的效果

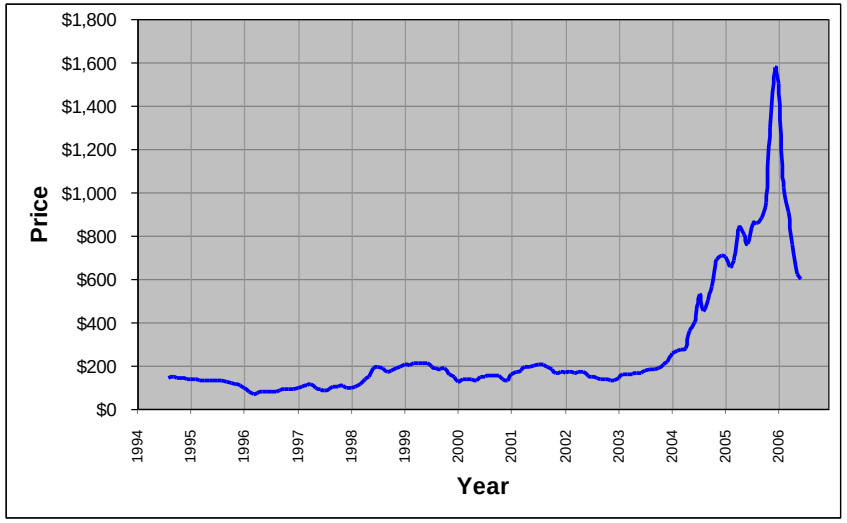
二氧化硫配额市场活跃

- The SO_2 allowance market responds to a variety of signals. Although the historical trend was stable (in the $200 per ton range) for a decade, prices in the last year have climbed in anticipation of lower caps. 很多信号影响二氧化硫排污交易市场。尽管2004年以前的十年里二氧化硫配额市场稳定，但由于预期二氧化硫排放总量限值要下降，去年的二氧化硫排污配额的价格迅速上升。

Private SO_2 Allowance Transfers



SO_2 Allowance Price (per ton)



Current market price on 15 Sept, 2006

DATE	SPEC	TERM	BID	OFFER	LAST
15 Sep	SO2	2006	$585.00	$605.00	$590.00
15 Sep	SO2	2007	$584.00	$604.00	
15 Sep	SO2	2008	$580.00	$600.00	

SO2 evomark

Aug 2006

END OF MONTH SETTLE PRICE	MONTHLY AVERAGE
655.00	674.24

Monitoring & Reporting Emissions 排污的监测和报告

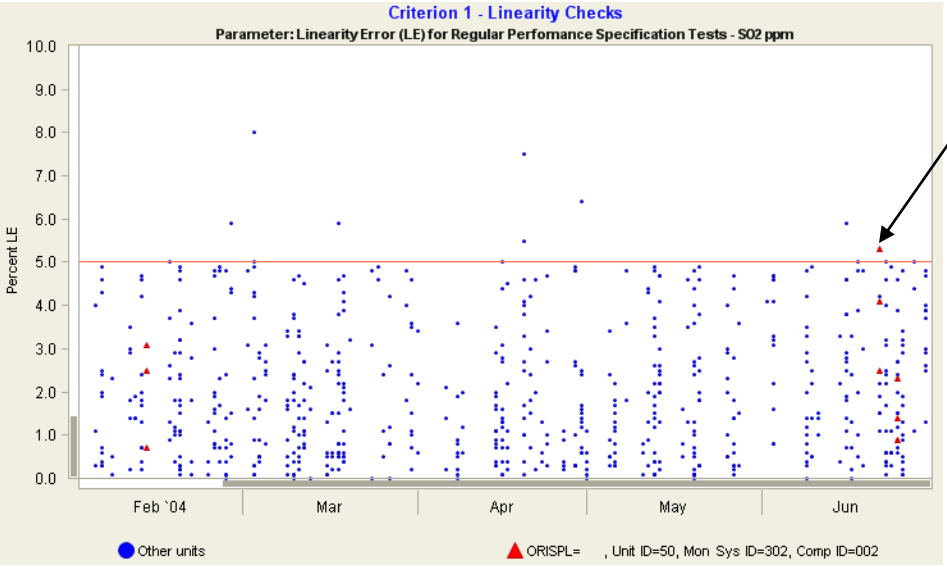
- Monitoring of emissions is the foundation of a Cap & Trade program. Continuous Emissions Monitors (CEMS) are used by 36% of ARP units but account for 96% of total SO_2 emissions.排污监测是实行排污交易的基础。有36％的酸雨项目使用连续排污监测器，但是他们占二氧化硫排放总量的96％。
- U.S. EPA does not certify CEMs, rather, it establishes performance standards for quality control and accuracy. This is intended to encourage innovation among equipment manufacturers. 美国环保署没有开展连续排污监测器认证，不过，他建立了一个质量控制和保证的性能标准。这样做的目的是鼓励仪器生产商进行创新。
- ARP provides flexibility for low emitting sources where the use of CEMs is not cost-effective. Note that alternative monitoring methods error on the side of over reporting due to their lower accuracy. 酸雨项目为排污少的污染源提供了更大的灵活性，这些污染源如果使用持续排污监测器是不划算的。注意，替代监测方法的高报误差是它们的准确性低导致的。
- Reporting, feedback, and auditing is all electronic. 报告、反馈和审计都是电子的。
- Public has access to data (CAMD Data and Maps): http://cfpub.epa.gov/gdm/ 网上数据公开

Testing of a new CEMs on the stack. Stringent quality assurance of monitoring procedures is the foundation of accurate emissions reporting.

在烟囱上测试一个新的连续排污监测器。严格的监测程序的质量保证是准确的排污报告的基础。

Audits 审计

- MDC (Monitoring Data and Checking) application allows sources to check data before submitting to EPA. 监测数据和核查的应用使得污染源可以在给环保署提交报告前核实数据
- Emissions Tracking System performs Electronic Audit on 100% of submissions. 对所有提交的报告通过排污跟踪系统实行电子审计
- EPA and states perform on-site audits. 环保署和各州实施当场审计
- Substantial investment in information technology: 对信息技术的巨大投资
  - providing free software tools to sources (such as MDC) 给污染源提供免费软件
  - Data Warehouse of historical emissions (hourly) open to public 历史排污数据库公开
  - statistical analysis of data 数据的统计分析
  - tools for policy development and assessment 政策制定和评估工具



Statistical analysis of CEMs test results
连续排污监测器的测试结果的统计分析

Compliance & Enforcement 达标和执行

- Determining compliance: compare emissions to allowances. 达标确认：对比排污配额
- 99.9% compliance rate 99.9%的达标率
- Assessing penalties for non-compliance 评价不达标惩罚
  - U.S. penalties provide for automatic offset (deduct allowance from next year's allocation) and financial penalty ($3,000/ton of SO_2) as well as possible civil and criminal penalties 自动抵消 （从下一年的排污配额里扣除），罚金 （每吨二氧化硫3000美金），和可能的民事和刑事处罚
- ARP 2005 results (3,394 units processed) 2005年酸雨项目成果 （3394个）
  - without critical errors: 3,230 不严重违规的：3230
  - with critical errors: 164 (affect SO_2 emissions) 严重违规的：164个
  - responded quickly & corrected critical errors: 147 及时反应和改正的：147个
  - more challenging resolutions: 17 有更大的决心的：17个
- CAMD works with sources to correct critical errors ahead of reporting deadlines. CAMD与污染源一起在报告截止前改正违规行为
- Creating a culture of cooperation and compliance where government and companies can work together to improve compliance 建立合作和达标文化，让政府和企业一道致力于达标率的提高

Advantages of Cap & Trade 排污交易的优点

- Certainty that a specific regional emissions level is achieved and maintained
- More regulatory certainty, compliance flexibility and lower permitting and transaction costs for sources
- Fewer administrative resources needed by industry and government
  - Government is focused on setting goals & assuring results
- Incentives for technology innovation and early reductions
- Can harmonize with a variety of other mechanisms at national and regional level.
- Lower compliance costs make further improvements feasible
- 保证一定的区域性排污水平实现和保持
- 更强的法规确定性，达标灵活性，更低的限值和交易费
- 只需要很少的工业和政府行政资源，政府只集中设定目标和确保结果
- 鼓励技术创新和超前减排
- 与国家和区域水平的各个其他机制很好地融合
- 更少的达标成本使下一步的进步变得更加可行

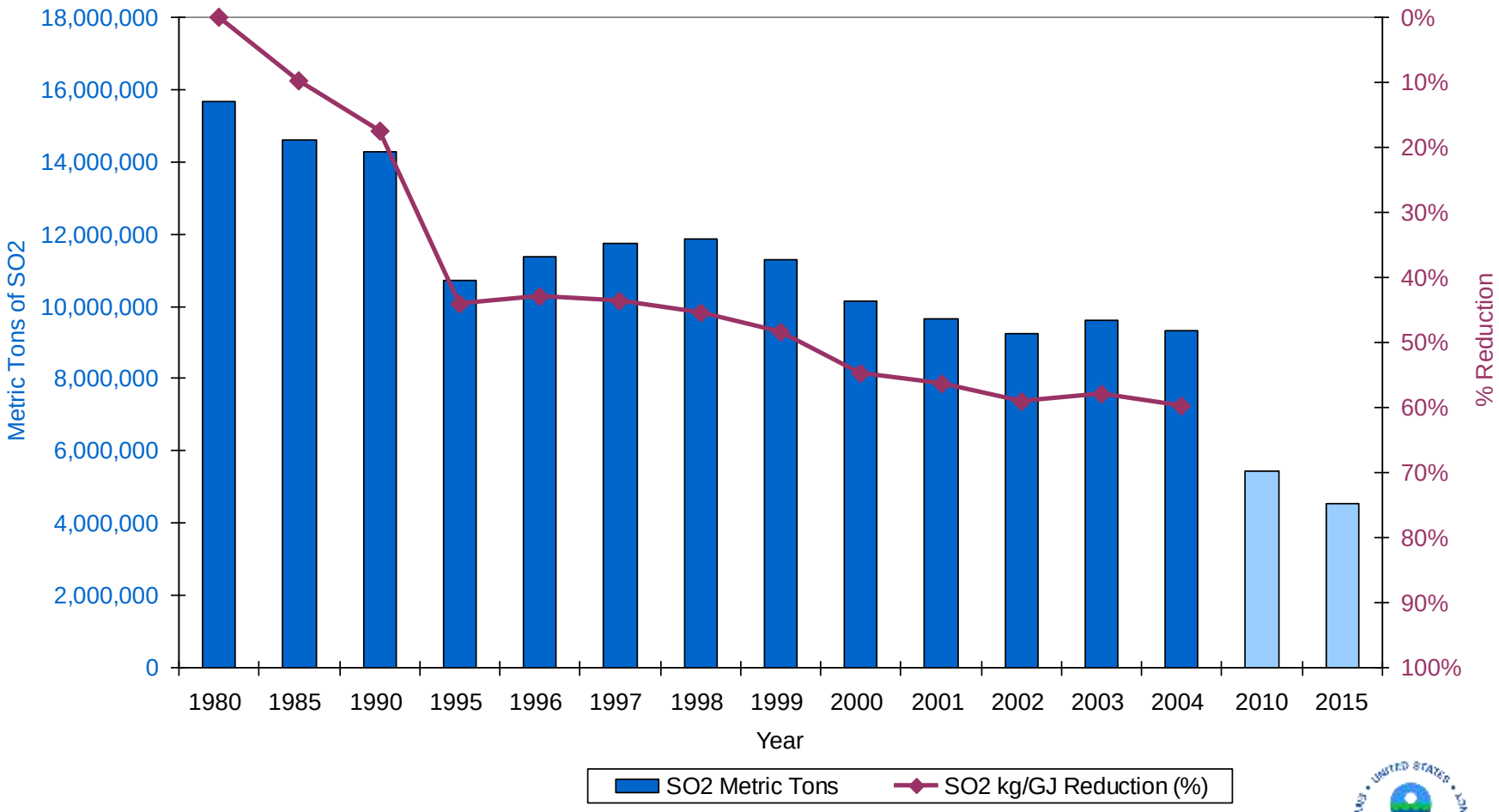
年度达标成本低

预计的2010年的达标成本

- 成本低的原因
  - 各种消减方法的竞争
  - 持续的技术革新的刺激机制
  - 储存在时间上提供了灵活性
  - 配额价格为决策提供了基准
  - 交易不受限制

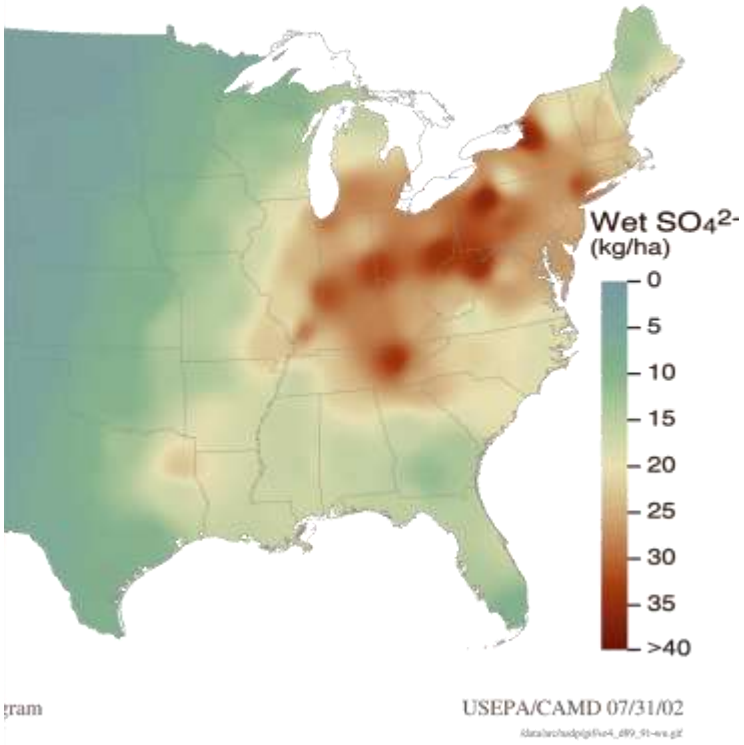
U.S. Acid Rain Program Results: Emission & Intensity Reductions

美国酸雨项目成果：排放量和强度的下降

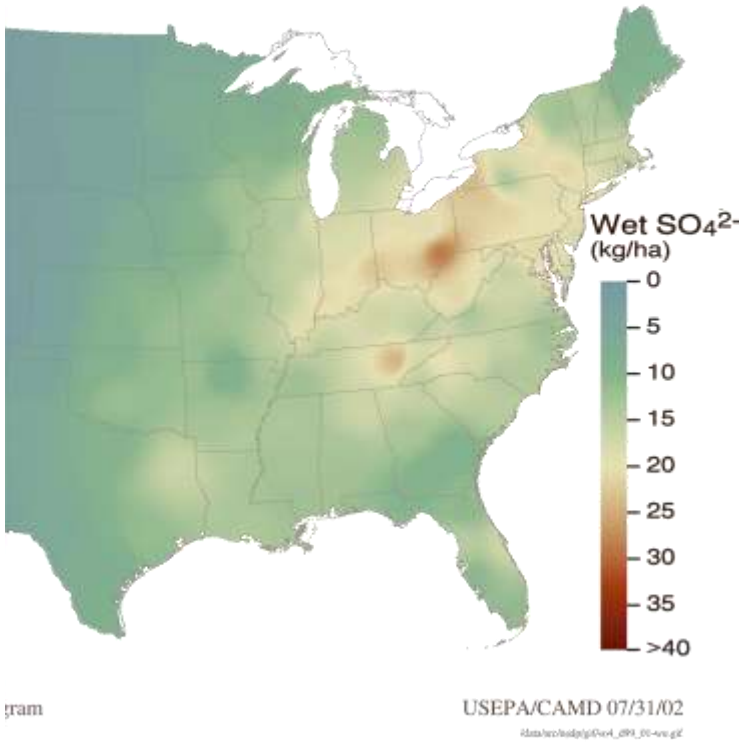


湿硫酸盐沉积的减少

1989-1991

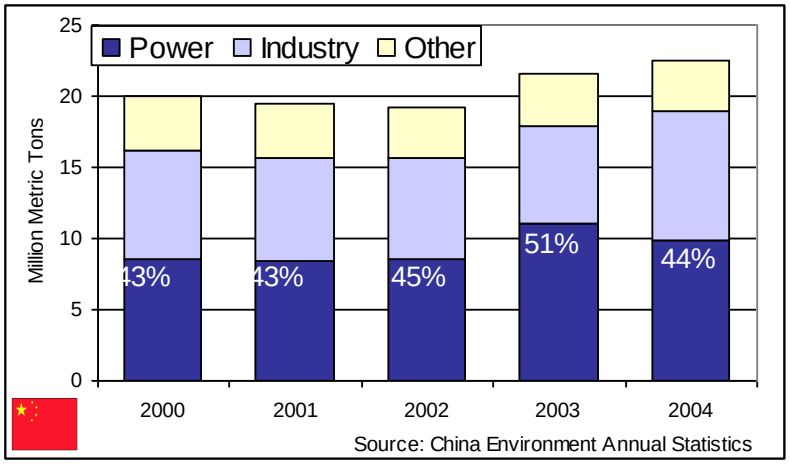


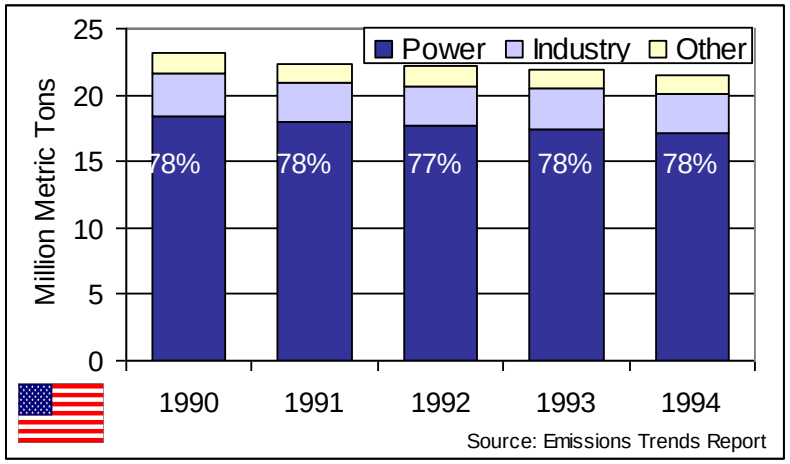
1999-2001



Point of Regulation法规

SO_2 Emissions from Fuel Combustion





- Contribution to total emissions
- Options to cost-effectively control emissions
- Ability to measure and report emissions
- Number of sources
- Potential for leakage (shifting emissions)
- Fairness
- 对排污总量的贡献
- 经济有效的排污控制选择
- 测量能力和排污报告
- 源的数量
- 泄漏的潜在威胁 （移动源）
- 公平

ARP Units by Fuel Type

从燃料总类看酸雨项目的发电机组

- Coal-fired units comprise 31% of the ARP but are responsible for over 96% of SO_2 emissions in 2005
- 燃煤机组占31%，但对二氧化硫排放的贡献率是96%

Acid Rain Program Units 2005			
FUEL	**2005 SO2 MASS (tons)**	**AVG SO2 RATE (lbs/mmBtu)**	**COUNT**
Coal	**9,828,819**	**0.948**	**1,061**
Residual Oil	338,113	0.748	150
Pipeline Natural Gas	34,042	0.013	2,093
Coal Refuse	7,619	0.500	2
Other Oil	5,387	0.456	11
Petroleum Coke	2,686	0.389	1
Diesel Oil	1,757	0.061	70
Refuse	1,674	0.226	1
Other Gas	1,408	0.033	12
Wood	887	0.161	5
Natural Gas	86	0.001	42
Process Gas	68	0.017	3
NA	2	0.000	14
TOTAL	**10,222,548**		**3,465**

(Source EPA; values may vary somewhat from official 2005 'true-up' numbers.)

ARP Installed SO_2 Controls by Input Capacity

根据供热能力统计酸雨项目里安装的脱硫设施

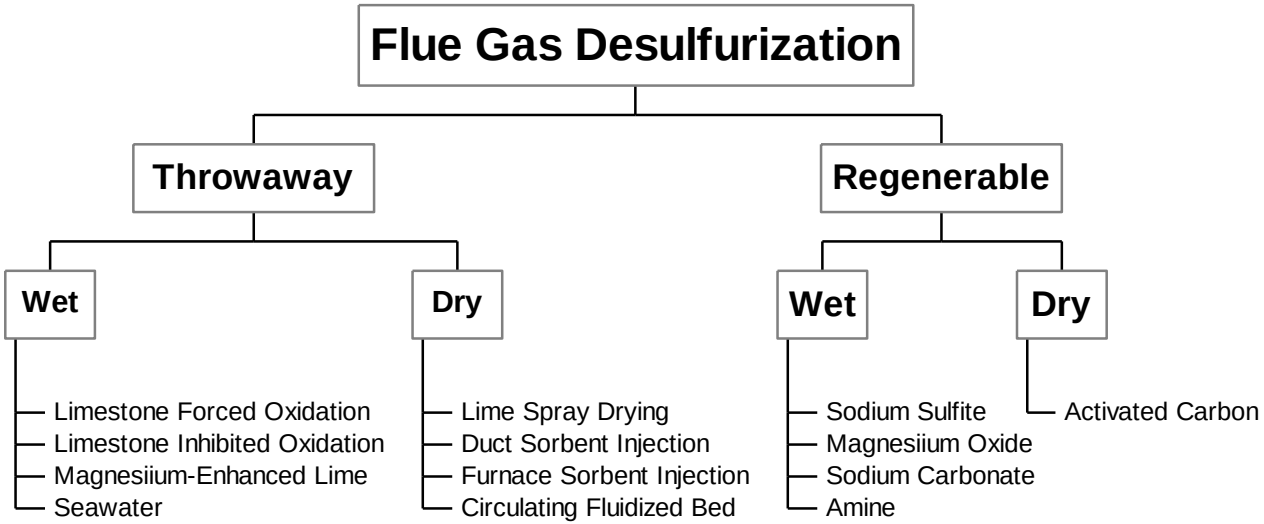
Max Heat Input Capacity (mm/Btu)	Count All Units	Count Units With SO2 Controls
NA	11	
0-500	500	17
500-999	563	14
1000-1999	1,146	52
2000-up	**1,245**	**182**
TOTAL	**3,465**	**265**

Less than 10% of ARP units have SO_2 Controls but they are concentrated in the largest units. 不到10%的酸雨项目有二氧化硫控制但是他们都集中在最大的项目上

(Source EPA; values may vary somewhat from official 2005 'true-up' numbers.)

Flue Gas Desulfurization (FGD)尾气脱硫

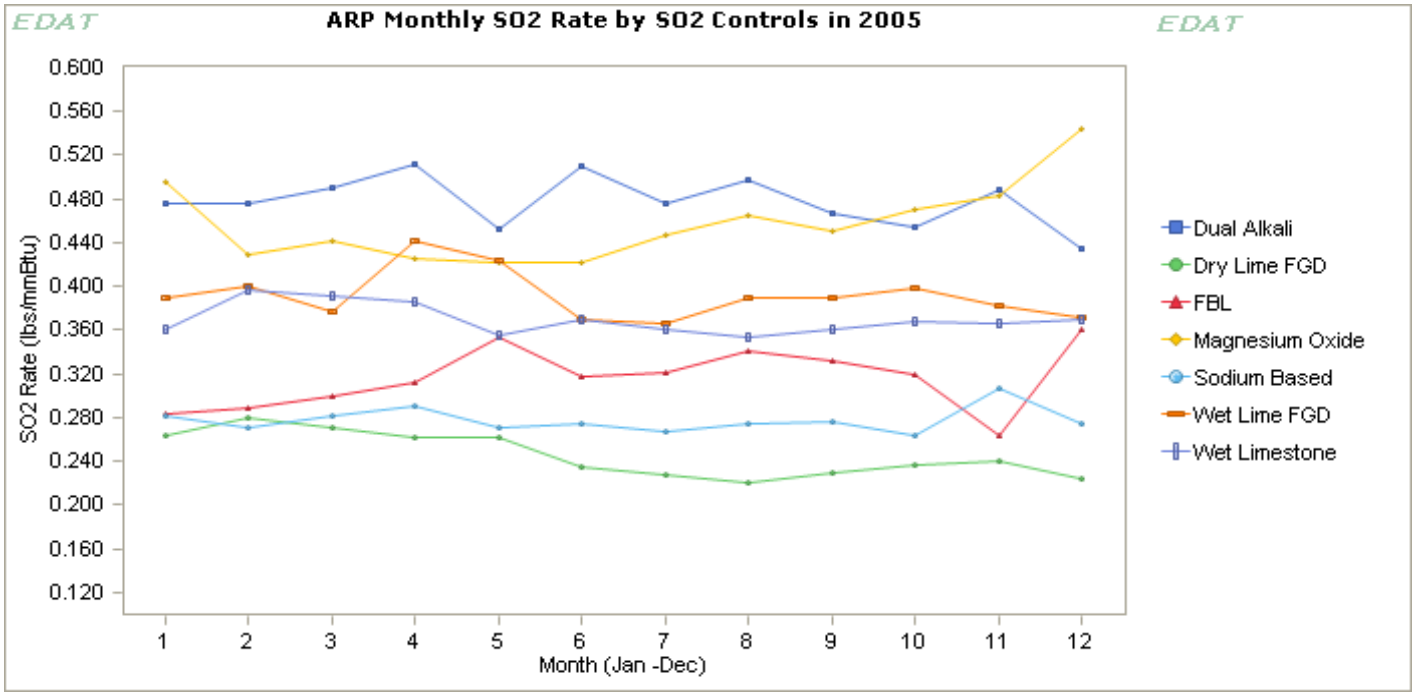
- ARP units utilize many of the Flue Gas Desulfurization (FGD) controls listed below but the decision on what technology to install is made solely by plant operators. 酸雨项目使用了以下很多尾气脱硫技术，决定使用哪种技术的是工厂自己



ARP Installed SO_2 Controls by Type

ABBREV	SO2 CONTROLS	COUNT
DA	Dual Alkali	5
DL	Dry Lime FGD	35
FBL	Fluidized Bed Limestone Injection	15
MO	Magnesium Oxide	3
O	Other	25
SB	Sodium Based	13
WL	Wet Lime FGD	65
WLS	Wet Limestone	104
TOTAL		**265**

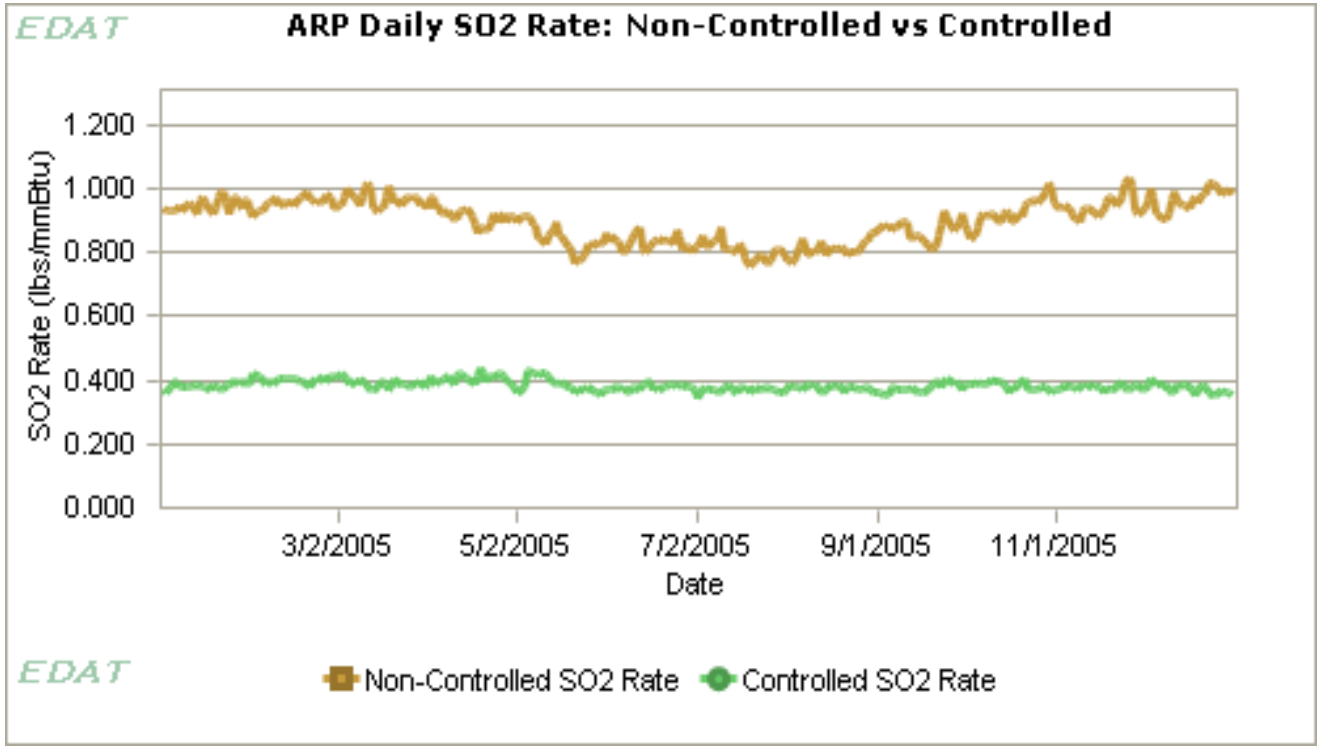
A range of control efficiencies can be seen in aggregate monthly SO_2 rates.
从图可以看出不同脱硫技术的脱硫效率



(Source EPA; values may vary somewhat from official 2005 'true-up' numbers.)

ARP Aggregate SO_2 Rates in 2005 2005年酸雨项目累计二氧化硫排放率

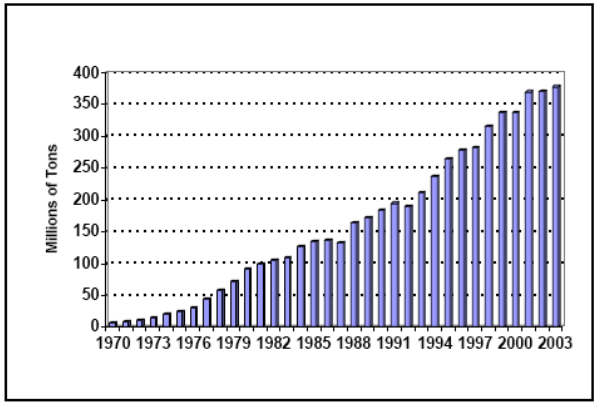
The aggregate SO_2 Rate for ARP Controlled units (.383) is less than half that of Non-Controlled units (.891) 酸雨项目的有脱硫设施的机组的累计二氧化硫排放率还不到普通机组的排放率的一半



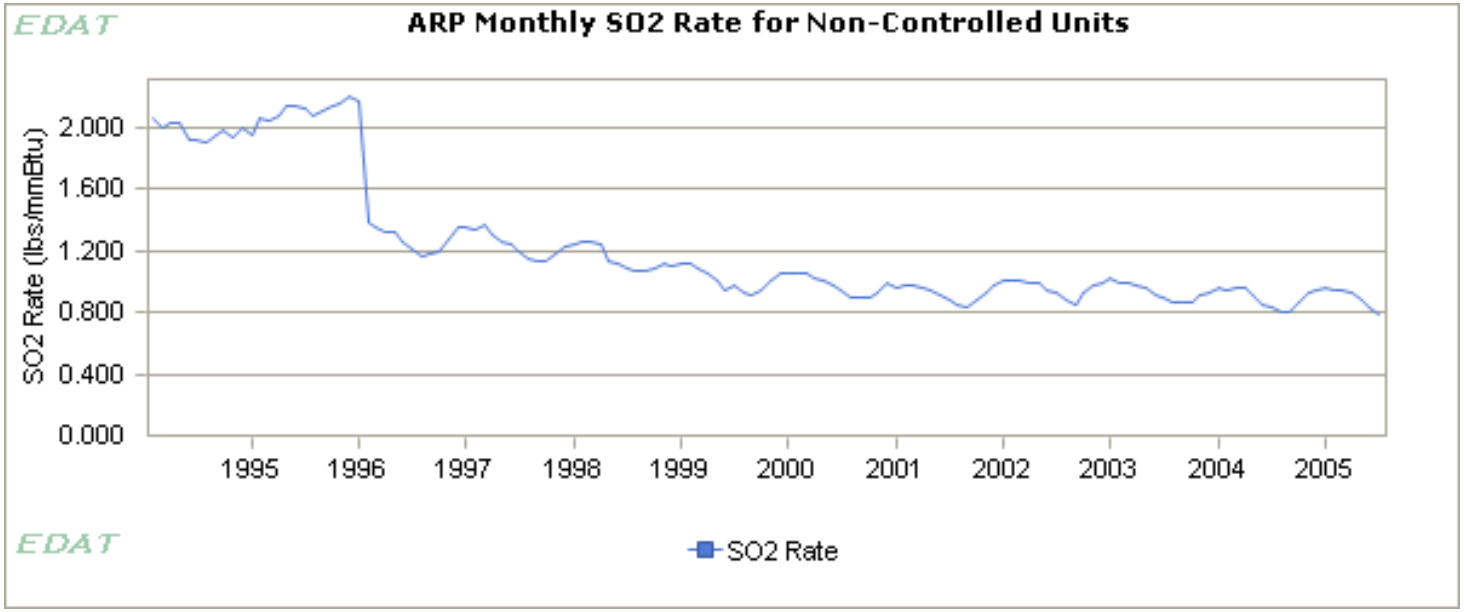
(Source EPA; values may vary somewhat from official 2005 'true-up' numbers.)

ARP Units Without SO_2 Controls Also Lower SO_2 Emissions
没有使用脱硫技术的酸雨项目单位也降低了二氧化硫排放

- ARP units without SO_2 controls have dropped their SO_2 rates primarily through the use of low-sulfur coals (< .61% low; 0.61-1.67% medium; > 1.67 high). 主要通过使用低硫煤（低于0.61%）
- Shipments of Powder River Basin coal (.2 - .54% sulfur) have grown to meet this demand.



Source: Wyoming State Inspector of Mines 1975 - 2003.
Figure 3-1 Statewide Coal Production (1970 - 2003)

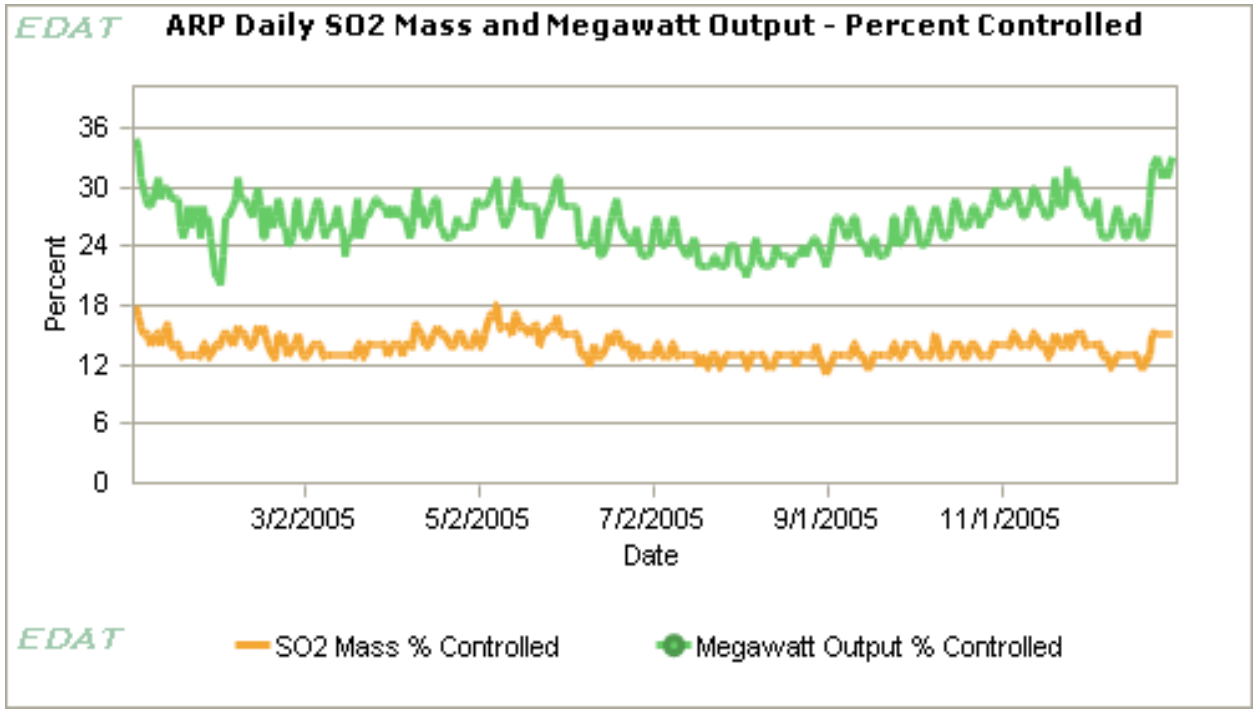


(Source EPA; values may vary somewhat from official 2005 'true-up' numbers.)

ARP Units: SO_2 Emissions and Megawatt Output in 2005
2005年二氧化硫排放和电力产能

Controlled units produced 26% of megawatt output but only 14% of SO_2 emissions in 2005。 2005年，有脱硫技术的机组生产了26%的电却只排放了14%的二氧化硫

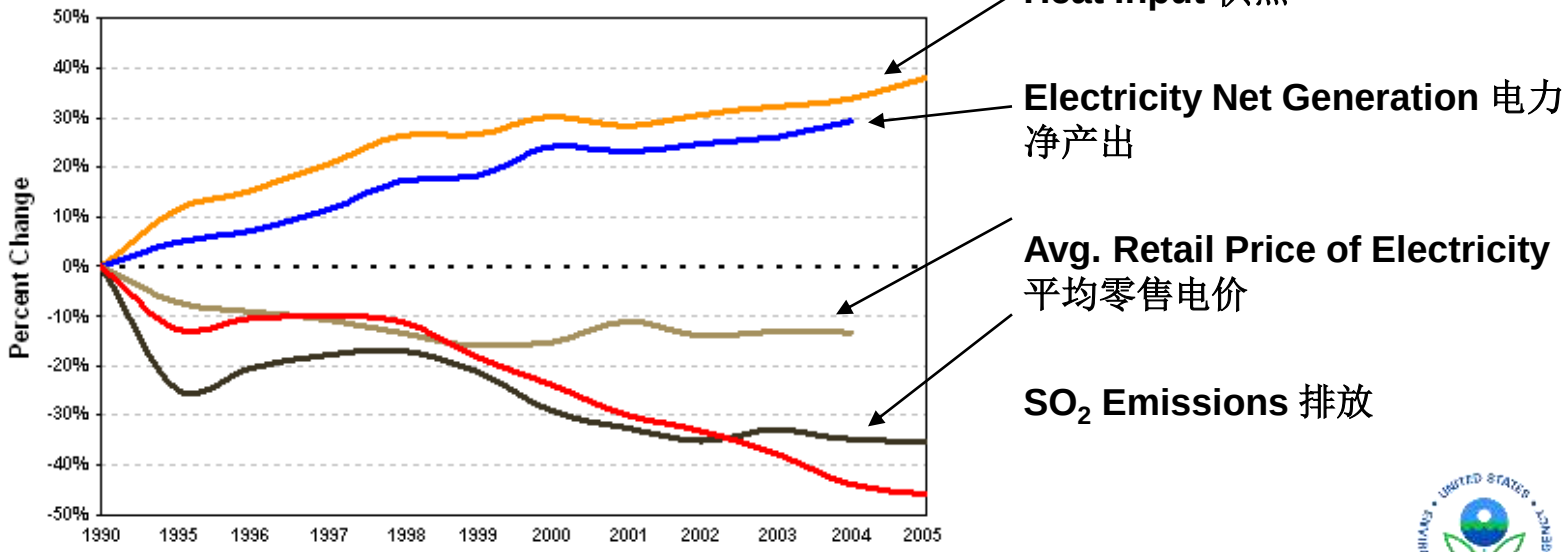
ARP Units	Non-Controlled	Controlled	Total	Percent From Controlled Units
SO2 Emissions (tons)	8,816,323	1,406,225	10,222,548	14%
Megawatt Output	2,017,240,681	715,008,277	2,732,248,958	26%



(Source EPA; values may vary somewhat from official 2005 'true-up' numbers.)

Economic Growth and Environmental Technology Go Together
经济和环境技术同步发展

- ARP benefits exceed program costs by a 40:1 ratio driven by: 酸雨项目的收益大于成本的40倍
  - Reduced premature deaths 降低早死率
  - Lowered aggravation and incidence of heart and lung ailments 减少病情恶化和得心肺疾病的风险
  - Increased worker productivity 提高工人的生产力
- According to Environment Business International, the global environmental market will reach $1 trillion by the end of the decade. 根据EBI的预测，到2010年底，全球环保市场将达到1万亿美元
  http://strategis.ic.gc.ca/epic/internet/inptg-sc.nsf/en/pg00056e.html
- A vigorous domestic environmental technology base will be essential to competing in this arena internationally. 活跃的国内环境技术基地将在国际竞争舞台上发挥重要作用
- **ARP achieved significant reductions in SO_2 emissions while electricity demand and fossil energy use increased substantially but real electricity prices declined.** 酸雨项目在二氧化硫减排方面取得了很大的成绩，在电力需求和化石能源使用大大增加的情况下，实际电价下降



谢谢

Contact: kokopeli.peter@epa.gov

For more information:

http://www.epa.gov/airmarkets