US SO_2 Emissions Trading

Rethinking Decarbonisation Incentives – Policy Case Studies

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This case study has been developed for the UK's Energy Systems Catapult under the *Rethinking Decarbonisation Incentives* project, aiming to draw lessons from international experience of policies to improve the framework of economic drivers for decarbonisation in the UK.

US Title IV of the Clean Air Act Amendments (CAAA) established an emission trading scheme (ETS) to reduce SO_2 emissions and therefore to improve human health and the environment. The scheme, called the Acid Rain Programme (ARP), set a national cap on SO_2 emissions from power plants. The programme was implemented in two phases. During phase I from 1995-1999, the 263 plants responsible for the largest volume of SO_2 were subject to an interim emissions cap. In phase II from 2000 and continuing indefinitely, the programme was expanded to include virtually all fossil-fuel electricity generating facilities.

This case study discusses the political context around designing the scheme, key design elements, and the economic benefits associated with the scheme. The case study also reviews the challenges associated with the attempts to alter the scheme (i.e. attempts to reduce the cap).

Key findings

- In the first decade of operation, the ARP cap-and-trade scheme delivered significant emission reductions compared to the baseline by cutting emissions by more than half. Studies show that cost savings compared to command and control instruments were achieved, although there are large variations in the estimates provided.
- The experience of designing ARP shows the importance of providing some degree of policy certainty to the regulated entities to facilitate planning and limit price volatility in early years. Setting the rules of the ARP well in advance allowed the regulated entities have time to adjust.
- There is a trade-off between predictability and flexibility. The experience of the ARP suggests that the statutory nature of the programme meant it was predictable and transparent. However, this came with a cost in terms of flexibility: any changes to the programme needed to go through the Congress, which proved to be difficult.
- The lack of supplementary regulation was seen as important in order to minimise distortions in the cap and trade scheme. Companies had the opportunity to cut emissions in a cost-effective way. The flexibility for the regulated entities to decide on their compliance strategy is key to deliver cost-effective emission reductions.
- Cap-setting methodologies, including underlying approaches to data and revisions to the cap, need to be clarified upfront. The attempts to change the cap of the ARP failed and the introduction of a new parallel trading scheme (Cross-State Air Pollution Rule, CSAPR) reduced confidence in the ARP, resulting in the collapse of its allowance price. The allowance market is essentially a Government-created market that requires regulated entities' confidence to sustain.

Abbreviations

ARP	Acid Rain Programme
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAIR	Clean Air Interstate Rule
CSAPR	Cross-State Air Pollution Rule
EPA	Environmental Protection Agency
ETS	Emissions Trading Scheme
GHG	Greenhouse gas
NAAQS	National Ambient Air Quality Standards

Nomenclature

Btu	British thermal unit
CO	Carbon monoxide
$MtSO_2$	Million tonnes of sulphur dioxide
NOx	Nitrogen oxides
O_3	Ozone
PM	Particulate matter
SO_2	Sulphur dioxide
tCO_2e	Tonnes of CO_2 equivalent

Acid Rain Trading Programme

Policy narrative and governance

The Clean Air Act (CAA) gives the US Environment Protection Authority (EPA) the authority to set country-wide ambient air concentrations for "criteria pollutants". Such limits have been set for particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), and lead, known as National Ambient Air Quality Standards (NAAQS). Individual states can set stricter pollution standards if desired[1]. The Acid Rain Programme was established under Title IV of the 1990 Clean Air Act Amendments (CAAA) with the objective of setting a national cap on SO_2 emissions from power plants. The programme also has an objective to reduce NO_x emissions but these are achieved through a more traditional regulatory approach as it does not 'cap' NO_x emissions nor does it utilise an allowance trading system[2]. Therefore, the focus of this case study is on the SO_2 elements.

In 1988 Vice President George H.W. Bush made the environment an important part of the presidential campaign, explicitly promising to update the CAA and to cut acid rain by half. An emission trading scheme (ETS) was considered to be politically more feasible than an environmental tax (see section on *Political Context* for further details) and the CAAA, including the SO_2 emission trading scheme, was signed by then President Bush in 1990.

The objective of the policy, i.e. the cap of the emissions, is set in the CAAA. The CAAA also appoints EPA as the administrator of the programme: it issues allowances, collects and verifies emission data, tracks allowance transaction data, assesses and enforces compliance and communicates information about the programme.[3] EPA does not have the authority to alter the cap as it is set in the law itself.

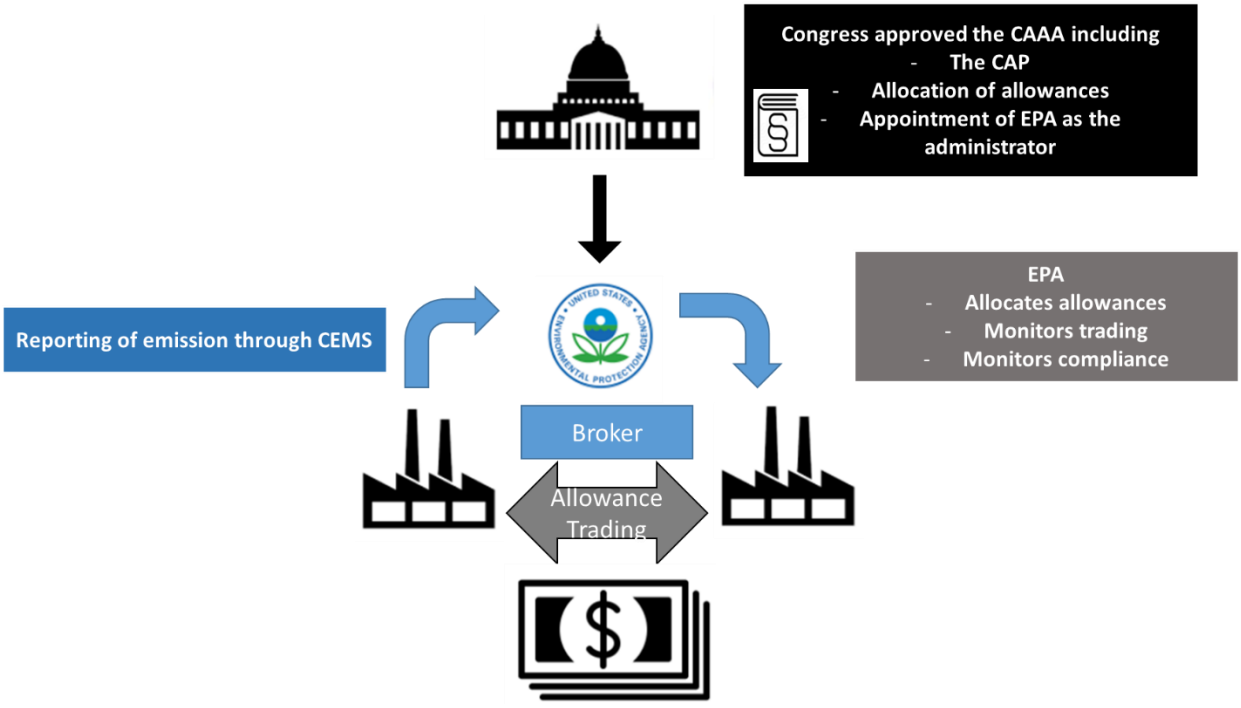

Figure 1 Governance structure of the Acid Rain Programme (SO_2)

[1] EPA, Border Air Quality Strategy: Unites States – Canada Emissions Cap and Trading Feasibility Study, 2005
[2] https://www.epa.gov/airmarkets/acid-rain-program
[3] Napolitano, S. et al.: The US Acid Rain Program: Key insights from the Design, Operation, and Assessment of a Cap-and-Trade Program, 2007

Coverage, obligated entities and eligibility

The Acid Rain Programme was implemented in two phases. During phase I from 1995-1999, the 263 plants responsible for the largest volume of SO_2 were subject to an interim emissions cap equivalent to a maximum 2.5 pounds (0.001 tonnes) of SO_2 per million Btu of heat input. In phase II from 2000 and continuing indefinitely, the programme was expanded to include virtually all fossil-fuel electricity generating facilities[4] and a cap of nine million tonnes implying an average emission rate of less than 1.2 pounds (0.0005 tonnes) of SO_2 per million Btu.[5] The cap was increased at the beginning of Phase II to account for the inclusion of new sources (amongst other adjustments) and finally set to approximately 9 million tonnes which is about half compared to the early 1980s levels.[6][7] The ARP covered approximately 75% of the SO_2 emissions in 1990, see Figure 2 below.

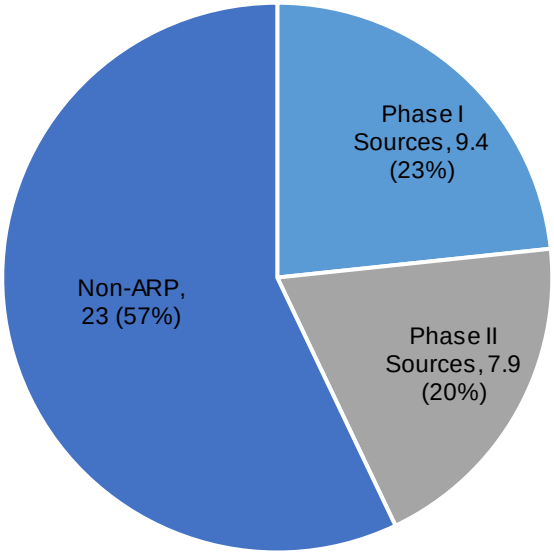

Figure 2 Coverage of the Acid Rain Programme in terms of SO_2 emissions in 1990 ($MtSO_2$)[8]

Mechanism and economic incentive

In an ETS, the regulated entity needs to surrender emission allowances according to the level of emissions. Therefore, they need to make a decision whether to reduce emissions through abatement or buy additional allowances from the market. The key economic incentives relate to the allowance surrender obligation, the allocation of the allowances, banking and participation in the trading of allowances:

- The **emission allowance** defines the right to emit one tonne of SO_2. On an annual basis, each plant is required to surrender an allowance for every tonne of SO_2 emitted.
- The **allowances** are **allocated free of charge**.
- The scheme allows **banking** i.e. saving emission reductions for future use or sale. Banking allows companies to bring forward emission reductions and save allowances for future when the cost of further reductions is expected to be higher. Operators have the **flexibility** to decide how to best reduce emissions including installing pollution control equipment; switching to lower sulphur coals, fuel blends, or natural gas; employing energy-efficiency measures and/or

[4] Generating units larger than 25 MW were added to the programme.
[5] The allocation of Phase I and Phase II allowances can be found here: https://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol16/pdf/CFR-2011-title40-vol16-sec73-10.pdf
[6] Ellerman and Harrison, Emissions trading in the US: Experience, Lessons and Considerations for Greenhouse Gases, 2003
[7] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions
[8] Based on Fraas, A. and Richardson, N., Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions 2010 and EPA, Sulfur Dioxide Emissions

renewable generation; buying excess allowances from other sources; or using a combination of these and other options.[9]

- **Participation** in the trading of the allowances is **not restricted** and therefore anyone may acquire allowances including private citizens, corporations, municipalities, brokers environmental groups among others.[10]

Compliance

Sources must annually surrender one allowance for each tonne emitted. Title IV of the CAAA defined a penalty of $2,000 per tonne in 1990, which is annually adjusted for inflation and imposed on those who do not have enough allowances to cover their annual emissions.[11] The 2005 penalty fee was set at $3,042 per excess tonne. The penalty is approximately 10 times larger than the cost of the allowance at that time. In addition, sources also need to surrender future year allowances to cover any shortfall.[12] Each source must implement an EPA certified monitoring system CEMS (Continuous Emission Monitoring System) that continuously measures and records mass emissions of SO_2 to account for every tonne of SO_2 emitted.[13] Records are also made publicly available.

Effectiveness and cost effectiveness

The programme has been effective in reducing SO_2 emissions (see Figure 3). The SO_2 emissions from power plants fell by 36% between 1990 and 2004 and the programme has achieved near full compliance over the years.[14] It has been acknowledged that the programme is more cost effective when compared to alternative regulation such as uniform performance standards but there is a large variation in the annual cost-saving estimates provided. Ex ante studies estimate cost savings of $250 million to $360 million for Phase I, and savings of $784 million to 2 billion for phase II.[15][16] Furthermore, there are no reported air pollution 'hot spots' or adverse distributional impacts as a result of the programme.[17]

Actual costs to EPA to implement the Acid Rain Programme during the five years following the CAAA are estimated to be $44 million, or 4% of total costs to implement the CAA in the same period. According to EPA, the number of people involved in administering the Acid Rain Trading programme is a third of what would be required for a more conventional air pollution control programme; which includes fixed emission limits for all plants.[18]

More recently, the challenge has been the treatment of the banked allowances in the revisions of the programme. Ultimately this lead to the collapse of the SO_2 allowance price, as described in the Section on *Key Design Elements*.

Political context

Prior to the approval of the amendments of the CAA there were lots of discussion on the relative merits of market based mechanisms vs command and control[19]. However, according to the available literature there was less debate over trade vs tax. In 1988, Vice President George H.W. Bush made the environment an important part of the presidential campaign, explicitly promising to update the Clean Air

[9] United States Environment Protection Agency, EPA, The Facts about Capping and Trading Emissions, 2002.

[10] To participate in trading a general account needs to be opened with EPA. General accounts are different to the compliance accounts that are used to monitor compliance.

[11] EPA, Acid Rain Programme 2005 Progress Report, 2006

[12] United States Environment Protection Agency, EPA, The Facts about Capping and Trading Emissions, 2002.

[13] Ellerman and Harrison, Emissions trading in the US: Experience, Lessons and Considerations for Greenhouse Gases, 2003

[14] Schmalensee and Stavins, Lessons Learned from Three Decades of Experience with Cap-and-Trade , 2015

[16] Chan., H. et al., The Impact of Trading on the Cost and Benefits of the Acid Rain Programme, 2015

[17] See for example DG Environment, Assessment of Effectiveness of European Air Quality policies and Measures, 2004

[18] DG Environment, Assessment of Effectiveness of European Air Quality policies and Measures, 2004

[19] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.

Act and to cut acid rain by half.[20] The Clean Air Act Amendments were approved by the administration of then President Bush. Therefore it is reasonable to assume that as republicans are more tax averse in general, an environmental tax would not have been on the top of their political agenda. Furthermore, the US has lower environmental taxes relative to the OECD average, both in terms of share of tax revenue and GDP.[21] Therefore, it is unlikely that at the time a major environmental tax on power generators would have been initiated and approved by the legislators.

Political leaders' evaluations of how both costs and environmental benefits will be perceived by stakeholders are key in designing environmental policies. Indeed, in the case of the Acid Rain Programme, the policy makers faced the challenge of convincing environmental groups that the cap was low enough. The administration was also concerned about the economic impact of the bill. The adverse impacts of the acid rain were becoming increasingly clear and there was great concern about environmental acidification, particularly of forests and aquatic ecosystems.[22] The President wanted to improve air quality at the minimum possible cost to industry and the economy and believed that a market-based approach could accomplish this. Chan et al. (2012) suggest that without the market-based cap-and-trade architecture, it is unlikely that a ten million tonne reduction in SO_2 emissions (and associated costs) would have been endorsed by the Bush Administration or approved by Congress.[23]

Key design elements and success factors

An important aspect of the policy design was to give industry enough time to prepare for the new policy regime and therefore leave a gap between finalising the rules and implementing the policy. In the Acid Rain Programme the **rules were approved two years prior to the start of the programme** giving the industry time to adjust.

The design of the Acid Rain programme included decisions on key parameters of a cap-and-trade instrument such as the cap, geographic coverage, industry and source coverage, allocation of allowances, banking and the scope of the trading.

The cap

Economic theory suggests that the efficient level of pollution abatement is reached when the marginal cost of abatement (i.e. the cost of extra unit of emission reduction) equals the marginal benefit of abatement. However, in practise it may be difficult to estimate these with certainty due to imperfect information and difficulties in monetarily quantifying the benefits of additional abatement. The background analysis undertaken by the Bush Administration in the context of the 1990 CAA put a greater focus on the cost side in order to find a proposal acceptable for the industry. Therefore, analysts failed to foresee the substantial human health benefits and decreasing abatement costs associated with reduced SO_2 emissions.[24] Had these been fully appreciated, policy makers might have pursued an even lower SO_2 cap.[25] In summary, the literature suggests that the **decision on the cap** was more a political decision than an evidence-based one.

[20] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.
[21] Mefcalf, G.E., Environmental Taxation, What have we learned in this decade?, 2009
[22] Schmalensee and Stavinsky, The SO2 Allowance Trading System: The Ironic History of a Grand Policy Experiment, 2012
[23] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.
[24] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.
[25] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.

Allocation of allowances

Congress and the Bush Administration judged that it was politically infeasible to request SO_2 emitters to pay the Government for the emissions included in the cap and therefore decided that the allowances would be allocated freely. In particular, the **free allocation of allowances was critical for gaining the support of the expected "losers" of the new policy**, i.e. high-sulphur-coal intensive power plants in the Midwest and their congressional representatives.[26]

Allowances are generally allocated in proportion to the average annual heat input during the three year reference period of 1985-1987 multiplied by the emission rate[27].[28] A small percentage of allowances (2.7%) are distributed through an auction conducted by the EPA to encourage trading and to ensure availability of allowances for new plants. The revenues from the auction are returned on a pro-rata basis to the owners of existing plants from whom the auctioned allowances were withheld.[29] In addition, 3.5 million bonus allowances (almost 1/3 of annual allowances) were awarded to plants that utilised scrubbers to achieve compliance and 300,000 bonus allowances were awarded to plants that installed renewable energy or implemented demand-side energy efficiency programmes to reduce emissions.[30]

As the cap and allocation of allowances are set in law, the programme was transparent and predictable for the industry. However, there was no flexibility to change these parameters. Therefore, the cap became irrelevant due to the reduction in emissions and failures to adjust the cap accordingly (see Section on *Key Design Elements* further details).

Banking

The ARP allowed sources to bank allowances i.e. save them for the future use. There were no restrictions on how many allowances sources were allowed to bank. Emissions from Phase I units were well below annual allocations of emissions allowances to those units. Therefore, banking contributed to substantial early emission reductions, demonstrated by the over-compliance to the cap.[31] The unused allowances formed a bank amounting to 11.6 million allowances by the end of Phase I. While the early years of Phase II were associated with a draw-down of banked allowances, resulting in emissions greater than the cap and a downward emission trend; see Figure 3.[32] **The bank played an important role in the political success of the programme**. The unused allowances in the bank implied that the firms had a vested interest in maintaining the value of those banked credits and thus supporting the continuation of the programme itself. Furthermore, banking provided an opportunity to harvest low-cost emissions reductions, and in some cases that effort may have brought forward innovations.[33] Banking also allowed the participants to smooth the transition to the more demanding cap in Phase II and higher expected marginal abatement costs.

Geographic coverage

Economic theory suggests that the size of the market, in this case the size of the allowance trading market, is positively correlated with efficiency gains as a bigger market provides a greater access to low-cost abatement. Additionally, the **geographic area covering nearly all states**[34] and allowance for inter-state trade are important features of the programme. Compliance data suggest that about one

[26] Chan et al., The SO2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.

[28] The emission rate depended on the plant category, there were 35 different types of plants receiving allowances based on a different formula, an average of this was 1.2 pounds (0.0005 tonnes) of SO_2 per million Btu.

[29] Ellerman and Harrison, Emissions trading in the US: Experience, Lessons and Considerations for Greenhouse Gases, 2003

[30] DG Environment, Assessment of the Effectiveness of European Air Quality Polices and Measures, 2004.

[31] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions

[32] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions

[33] Burtraw and Szambelan, U.S. Emissions Trading Markets for SO_2 and NO_x, 2009

[34] With the exception of Alaska and Hawaii, see Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions

third of the affected units in Phase I obtained allowances from other units, either by transfers within the firm or through purchase in the allowance market. As a result, an active and efficient market for SO_2 allowances has been created. This is demonstrated through small variation in the prices of the allowances, by the high volume of inter-firm trades, low transaction costs and by the development of an active and diverse contract and futures market.[35] However, the Acid Rain Programme excluded industrial sources. Industrial sources had the option to opt in but very few sources decided to do so.[36] It is unclear why this was the case although it could be linked to complexity of a trading scheme (real or perceived) and/or the stringency (or not) of existing standards for industry.

In addition to the emission reduction imposed by the cap, all areas need to meet separate national, health based ambient air quality standards. Therefore, no source may use allowances to emit more SO_2 which would then lead to a non-attainment of the SO_2 ambient air quality standards. Available evidence suggests that emissions **trading** has not impacted the attainment of air quality standards and therefore **has not adversely affected any specific region**. Moreover, the greatest reductions under the programme were achieved in the states with highest emissions.[37] However, recent literature suggests that the health costs of the ARP were larger compared to a counterfactual without trading i.e. uniform performance standards A potential explanation is the fact that facilities that faced higher marginal cost of abatement (such as due to higher transport costs of low-sulphur coal) also had higher health damage costs due to higher population density.[38] The trading shifted emissions from areas with lower marginal costs and lower population densities to the more densely populated areas.

Supplementary regulations

The 1990 CAAA largely avoided imposing additional regulations on any specific technical solutions that sources needed to apply or install [39] despite widespread scepticism about the cost and environmental effectiveness of the cap-and-trade itself.[40] Largely because of this heterogeneity, had the 1990 CAAA included a technology (most likely scrubber) mandate, aggregate compliance costs would have been much greater. Therefore, regulations that allowed **flexibility** for compliance and any technology choices were **key to realising its cost-effectiveness potential**.[41]

However, although the CAAA itself did not impose regulation on how to achieve emission reductions, sources needed to comply with other federal legislations such as the New Source Performance Standards (NSPS)[42] which could have kept costs above the theoretical minimum.[43] The NSPS often had the same requirements as the ARP.[44]

One key feature of the programme is the avoidance of costly verification of credits for each transaction. This has improved the liquidity of the allowance market.[45] However, this could also have been a risk and requires a robust MRV system to be in place.

[35] Ellerman et al., Emission in the US: Experience, Lessons and Considerations for Greenhouse Gases, 2003.
[36] DG Environment, Assessment of the Effectiveness of European Air Quality Policies and Measures, 2004
[37] EPA, Clearing the Air: The Facts about Capping and Trading Emissions, 2002
[38] Chan., H. et al., The Impact of Trading on the Cost and Benefits of the Acid Rain Programme, 2015
[39] Such as through specific pollution control technology requirements or performance standards for individual plants
[40] Chan et al., The SO2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.
[41] Chan et al., The SO2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.
[42] The NSPS of 1977 in effect required all coal-fired power plants built after 1977 to install scrubbers.
[43] Schmalensee and Stavinsky, The SO2 Allowance Trading System: The Ironic History of a Grand Policy Experiment, 2012
[44] Chan., H. et al., The Impact of Trading on the Cost and Benefits of the Acid Rain Programme, 2015
[45] Schmalensee and Stavinsky, Lessons Learned from Three Decades of Experience with Cap-and-Trade, 2015.

Performance

The overall performance of the programme is illustrated in Figure 3 below. Note that the Phase II started in year 2000 but emissions from the Phase II sources are presented also for years 1990-1999 to illustrate the emission reductions that took place later.

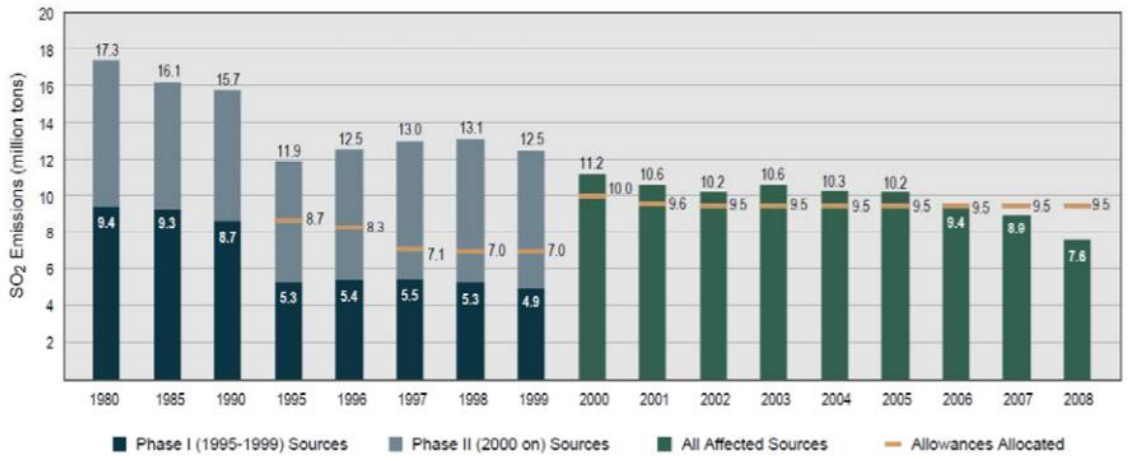

Figure 3 SO_2 Emissions from Acid Rain Programme Sources 1980-2008[46]

There was widespread concern that the market would lack sufficient liquidity (i.e. enough buyers and sellers) to function well.[47] A related concern was that incumbent firms might use the allowance market to construct barriers to entry against new entrants. To address these issues, approximately three percent of the allowances allocated to installations were retained by EPA and auctioned annually. However, these concerns did not materialise, and the allowance auction was not necessary for liquidity purposes. There is broad consensus that the **SO_2 allowance market operated transparently and fairly due to transparent data systems, public access to information and strict penalties for non-compliance among others.**[48]

More recently, the challenge has been the treatment of the banked allowances in the revisions of the programme and attempts to reduce the cap. Ultimately this lead to the collapse of the SO_2 allowance price. See the on Section on *Key Design Elements* for further details.

Key milestones

Towards the end of the 1990s, it was recognised that further reduction in SO_2 emissions were required in order to restore sensitive ecosystems from acid rain. However, the Congress failed to pass the Clear Skies Act 2002 with the objective to tighten the SO_2 cap. In 2005, the administration proposed the Clean Air Interstate Rule (CAIR) with the same intention to reduce the SO_2 cap. In part, this was done by applying more stringent emission requirements on some 'upwind' states, i.e. states whose pollution affects air quality in downwind states due to wind conditions, while maintaining the nation-wide cap. These up-wind sates were primarily mid-western states that were contributing to violations of EPA's primary ambient air quality standards for fine particulates in the eastern United States. CAIR required sources within those states to surrender two additional allowances for every tonne of SO_2 emissions,

[46] Source: Fraas, A. and Richardson, N., Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions, 2010
[47] Chan et al., The SO2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.
[48] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012.

effectively reducing the cap by two-thirds. As a result, the allowance prices in anticipation of CAIR rose.[49,50]

Another issue with the formation of the CAIR was the treatment of banked SO_2 allowances under Title IV of the CAAA. The transition from Phase I to Phase II under the Acid Programme did not create any issues with banked allowances because the details were written in the CAAA itself. Under the CAIR EPA proposed a stricter cap for SO_2 emissions by increasing the number of allowances sources had to surrender for each tonne of SO_2 emissions. Banked allowances acquired before 2009 could be exchanged 1:1 for tonne of SO_2 emitted, but CAIR required two allowances of 2010-2014 for each tonne emitted and after 2014 2.86 allowances for each tonne emitted. The final CAIR rules were published in 2005 given companies four years to adjust. With the one-to-one exchange of pre-2010 allowances, CAIR created an important incentive for early emission reductions.[51]

However, the D.C. Circuit Court of Appeals ruled that the CAAA Title IV SO_2 allowances could not be limited based on the source location to address other CAA requirements, i.e. ambient air standards.[52] Additionally, the ruling did not approve changing the relationship specified in Title IV of the CAA of one allowance for one tonne of emissions.[53] Therefore, the congressional attempt to confirm the reduction in the cap, which industry had already started implementing, was unsuccessful.[54] As a response to this, a new rule called Cross-State Air Pollution Rule (CSAPR) was finalised in 2011. CSAPR only employs allowance trade within states and does not employ Title IV allowances. In other words, a new programme was created that companies needed to comply with, and for which they were not allowed to use the old allowances whose banked reserve amassed to a significant amount.[55] Subsequently, the SO_2 (Title IV) allowance price collapsed and fell near to zero.[56] The key events that affected the development of the scheme are illustrated in **Figure 4** below.

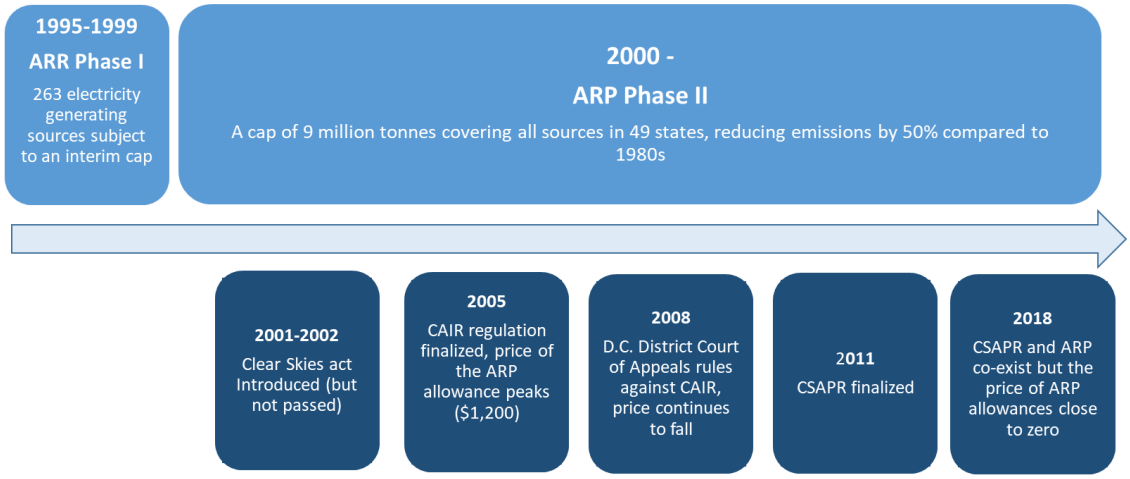

Figure 4 Development of the Acid Rain Programme [57]

[49] Schmalensee and Stavinsky, The SO2 Allowance Trading System: The Ironic History of a Grand Policy Experiment, 2012
[50] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions, 2010
[51] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions, 2010
[52] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012
[53] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions, 2010
[54] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012
[55] Fraas and Richardson, Banking on Allowances: The EPA's Mixed Record in Managing Emission-Market Transitions, 2010
[56] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012
[57] Based on Schmalensee and Stavinsky, The SO2 Allowance Trading System: The Ironic History of a Grand Policy Experiment, 2012

The total number of affected plants under ARP and CSAPR is presented in Figure 5.

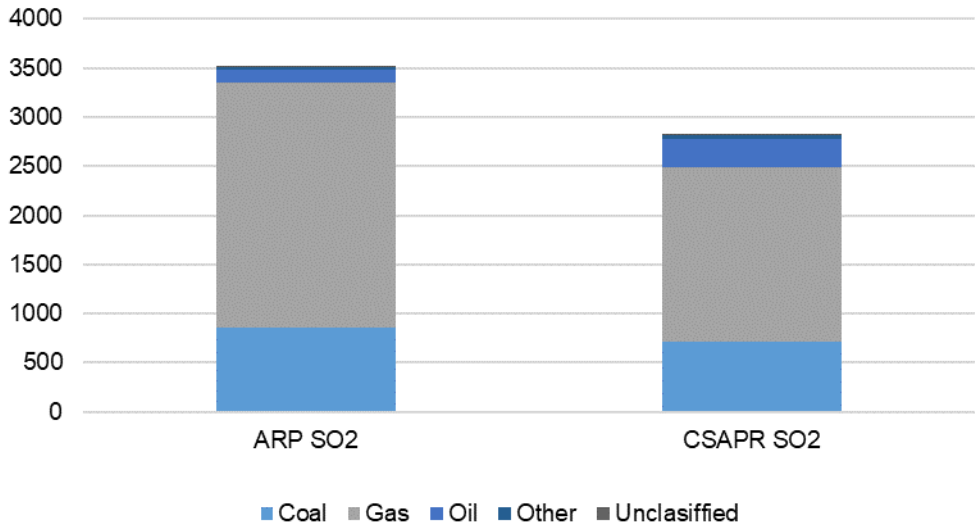

Figure 5 Affected Plants in ARP and CSPAR in 2015[58]

In 2015 the emissions from ARP affected sources were well below the cap at 2.2 million tonnes of SO_2 compared to the cap of 8.98 million tonnes. These emissions represent an 86% reduction to 1990 levels. After the reconciliation for compliance over 33.7 million ARP SO_2 allowances were banked and carried forward to the 2016 ARP compliance year.[59]

To sum, the emission trading system was highly successful in its first decade of operation delivering cost-effective emission reductions. The allowance market itself did not show any sign of malfunctioning. However, conflicts in the attempts to alter the programme to deliver greater emission savings ended the successful story prematurely.[60]

Estimated benefits of the scheme

The programme has been effective in reducing SO_2 emissions (see Figure 3). The SO_2 emissions from power plants decreased 36% between 1990 and 2004 while electricity generation from coal-fired power plants increased 25% over the same period. The option to bank allowances has implied that total emissions have at times exceeded the cap. Nevertheless, the programme has achieved near full compliance over the years.[61]

Cost savings resulting from the emissions trading in the Acid Rain programme are estimated to be significant. EPA itself estimated that the programme would deliver cost savings of $9.6 to $13.8 billion during the first 13 years in 1993-2010.[62]

However, most of the studies have attempted to provide estimate ex ante and indeed there are few very empirical studies that have used actual compliance data from Phase II. A recent study that fills this gap provides annual cost savings estimates of $240 million[63] using the data from 2002.[64] This is much lower

[58] Based on EPA, 2015 Program Progress – Cross-State Air Pollution Rule and Acid Rain Program, 2017
[59] EPA, 2015 Program Progress – Cross-State Air Pollution Rule and Acid Rain Program, 2017
[60] Chan et al., The SO_2 Allowance Trading System and the Clean Air Act Amendments of 1990: Reflections on Twenty Years of Policy Innovation, 2012
[61] EPA, Clearing the Air: The Facts about Capping and Trading Emissions, 2002.
[62] Chan, H. et al., The Impact of Trading on the Costs and Benefits of the Acid Rain Program, 2015
[63] 1995 US$
[64] Chan, H. et al., The Impact of Trading on the Costs and Benefits of the Acid Rain Program, 2015

than the ex ante costs saving estimates provided by earlier studies. The difference could be partly explained that the programme had not yet achieved compliance (i.e. the cap) in 2002, and therefore the expected benefits from trade had not yet been fully exploited. Other studies suggest that the technological development and the price fall in low-sulphur coal reduced the marginal abatement costs significantly during the ARP. Therefore, the flexibility to take advantage of these changes is the greatest attribute to cost savings, rather than trading per se.[65]

Monitoring, reporting and verification of emissions

Monitoring, Reporting and Verification (MRV) is key to emission trading. An accurate and transparent system needs to be in place to facilitate the trade. Without such system, the participants in the market would not have the confidence to trade on a commodity that they cannot verify themselves.

Each source must implement an EPA certified monitoring system CEMS (Continuous Emission Monitoring System) that continuously measures and records mass emissions of SO_2 to account for every tonne of SO_2 emitted. Records are made publicly available. The CEMS report hourly emission electronically and these data are verified and recorded by EPA. EPA has issued detailed regulations for CEMS including initial equipment certification procedures, periodic quality assurance and quality control procedures, record-keeping and reporting requirements, and procedures for filling in missing data periods. All CEMS must be in continuous operation and must be able to sample, analyse, and record data at least every 15 minutes.[66] It is estimated that CEMS increased the Phase I compliance costs of the Acid Rain Programme by about 7% but has proved to be an accurate method to account emissions compared to the cheaper 'materials balance' – an alternative approach to account SO_x emissions.[67]

The emissions data are made available online to promote transparency.[68] A transparent system of emissions reporting has been critical to the success of the programme, as well as promote by-in from the industry.

CEMS can also be used for monitoring and reporting of GHG emissions. For example, the EU-ETS requires N_2O emissions to be monitored and reported through use of CEMS. This is because emissions of N_2O (as for other air pollutants and some other GHGs) depends on a number of different variables including fuel characteristics, combustion technology and conditions, temperature of flue gas etc. However, CO_2 emissions, in particular from combustion activities, can be estimated to a relatively high degree of accuracy from standardised calculation methods taking into account fuel types and characteristics (and this is allowed for in the EU-ETS, for example). Therefore, for CO_2 emissions, particularly from combustion, CEMS is an additional cost that is not always required.

Application for regulation of GHG emissions

Emission trading in carbon emissions is already implemented in the EU and many other regions. The US experiences in SO_2 has been influential in designing emissions trading schemes, including the EU-ETS. The US experience, particularly during the first decade, demonstrated that cap-and-trade policies can have a significant impact on emission reductions and deliver these reductions in a cost-effective way.

The design and implementation of abatement policies, including emission trading, for air pollutants, such as SO_2, is generally more complex than for CO_2. This is because the monitoring of emissions is

[65] Carlsson, C. et al., Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade, 2000
[66] EPA, 2005
[67] Ellerman et al., Emission Trading in the US: Experience, Lessons and Considerations for Greenhouse Gases, 2003
[68] DG Environment, Assessment of Effectiveness of European Air Quality policies and Measures, 2004

more complex and requires more expensive technology (such as CEMS). Additionally, air pollutant emissions are not only influenced by fuel type and volume used but also the way in which they are combusted. Therefore, abatement technologies installed and the processes employed (e.g. for industrial manufacturing) make the accounting and monitoring of emissions more challenging (this is particularly true for CO_2 emissions)[69]. Finally, the impacts of GHG emissions are global whereas the impacts of air pollutants are more local and therefore the distributional impacts are less of an issue for GHG emissions.

To sum, the early success of the Acid Rain Programme suggests that the cost-effective reductions of CO_2 emissions through cap-and-trade programme are possible given that many of the complexities related to air pollutants do not apply with CO_2. However, the design of the emission-trading program is key. Ideally, the program design would give long-term policy certainty including information on how the cap or other key elements could be revised.

Key findings

In the first decade of operation, the ARP cap-and-trade scheme delivered significant emission reductions compared to the baseline and cost savings compared to command and control instruments. The ARP was very successful in the first decade in achieving significant SO_2 emission reductions and creating an active trading market. Studies reveal that ARP delivered significant cost savings compared to an alternative command-and-control policy instruments, although there are large variations in the estimates provided.

The experience of designing ARP shows the importance of providing some degree of policy certainty to the regulated entities to facilitate planning and limit price volatility in early years. In the case of the ARP, the rules were finalised and communicated two years ahead of the allowance trading.

There is a trade-off between predictability and flexibility. The experience of the ARP suggests that the statutory nature of the programme meant it was predictable and transparent. The transparency of the ARP implied that the management of the ARP did not involve any litigation, which is common with the regulatory emission trading schemes administered by EPA. These schemes are associated with less predictability and more litigation but can also be amended due to changes in market conditions[70].

A number of design elements, such as free allocation of allowances and banking, were critical for the acceptability and success of the policy. Free allocation of allowances was critical to get the buy-in from the industry. The provisions on banking have proved to be important providing the regulated sources more flexibility to adjust, this is particularly true for programmes that are implemented in phases, such as the ARP. In addition, transparent data systems, public access to information and strict and clear penalties for non-compliance have contributed to an excellent compliance record. These success factors are applicable in other contexts too.

The lack of supplementary regulation was seen as important in order to minimise distortions in the cap and trade scheme. An important design feature of the ARP was that the 1990 CAAA largely avoided imposing supplementary regulations on SO_2 emissions, whether through specific pollution control technology requirements or performance standards for individual plants. A common view is that an emission trading scheme is only able to achieve its full potential when sources are able to freely

[69] The EU-ETS requires the use of CEMS for N_2O emissions. For CO2 sources can use either calculation based-based or measurement-based (CEMS0 reporting.
[70] Personal communication with a policy expert on 29th of March, 2018.

choose its best response strategy, be it implementing abatement technologies or buying allowances from the market. However, sources do face supplementary regulation through other regulations such as New Sources Performance Standards that may have undermined the efficiency of the ARP.

The cap level is a key driver of the allowance price and therefore warrants a careful consideration. The Acid Rain Programme provided certainty and a strong price signal for the market at the beginning of the programme as a result of a relatively stringent cap and well-functioning allowance markets. However, it became evident that further reductions of SO_2 emissions were needed to fully restore ecosystems such as highly polluted lakes.

The experience of ARP reveals the challenges of altering key design elements, such as the cap or the use of the banked allowances, after the start of the programme. Attempts to alter the programme by reducing the cap failed and a new SO_2 trading programme was introduced in addition to the ARP. Part of this is attributed to the complexities of the ARP (i.e. the cap is defined in the law itself requiring the support of Congress to change it) rather than emission trading per se. Also, the need to alter the programme was at least partly attributed to the nature of air pollutants and the difference between upwind and downwind states i.e. pollution in upwind states affects air quality in downwind states due to wind conditions not relevant for CO_2 regulation. Furthermore, the collapse of the ARP may have also undermined industry's confidence in other ETS.

Therefore, the design of the scheme should be flexible to incorporate new or improved scientific evidence on achieving environmental (and health) targets. Evidence suggests that the initial decision on the level of the cap was more a political choice rather than a result of detailed modelling of the associated costs and benefits of air pollution abatement.[71] The tools and information to undertake such modelling have advanced significantly in recent years suggesting that a similar exercise to determine 'the right' level of the cap could look quite different now.

Finally, another critique of the trading programme is its failing to adapt to the information available. Allowance prices represent information about the marginal cost of emissions reductions – previously unavailable to regulators at this scale – but thus far programmes have not found a way to readily adapt.[72] This could mean adjustments to the cap or incorporation of floor prices to ensure that the price of the allowance would match the marginal cost of abatement to the extent possible. However, setting floor prices has its own challenges, particularly in the US context. Recent court rulings have stated that EPA cannot over-control emissions, i.e. setting policies that are more stringent than the underlying health and environmental concerns give cause for.[73]

[71] Referring to the earlier discussion on the SO_2 cap
[72] Burtraw and Szambelan, U.S. Emissions Trading Markets for SO_2 and NO_x, 2009
[73] EPA, Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS, 2006.

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