The Greenhouse Gas Emissions Trading Journey: Finding the Balance between Acceptance, Effectiveness and Emissions Reduction

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Business Administration

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Abstract

For over a decade this study followed designs for emissions trading schemes (ETS) that have emerged in response to global warming. An ETS is considered a cost-effective instrument to mitigate pollution (UNFCCC, 2006). Early in this study indications were that several operational ETSs struggled to achieve their emission reduction goals. Considering this problem, the study looks at the competing constraints of acceptance, effectiveness, and emissions reduction.

The parameters of an ETS can be adjusted in relation to these constraints and the study also considers the alignment of nine design factors to these constraints. The design factors considered are legislation, governance, compliance, rules, compensation, targets, phasing-in, coverage and the distribution of allowances. It emerges that adjustments in terms of factor alignment may affect a schemes ability to reduce emissions.

Other important factors sit outside the scope of this study, i.e. variations in greenhouse gas emissions as a result of the GFC and later COVID-19, also alternative mitigation policies, human adaptation, and innovative technologies.

Viewed in a comparative manner the main case studies are the antecedent US Acid Rain Program (US ARP), the European Union Emission Trading System (EU ETS) and the US Regional Greenhouse Gas Initiative (RGGI). Other ETS designs that provide data for the study include the UK Emissions Trading Scheme (UK ETS), the Carbon Pollution Reduction Scheme (CRPS), which later became known as the Australian Carbon Tax, and the Californian Cap and Trade Program (CCTP).

An effective ETS may perform adequately in relation to its’ goals for governance and compliance, although it can be shown that if the design leans too far toward acceptance the capacity for emissions reduction is diminished. According to the conceptual framework developed early in the study, over time the relationship between the constraints and the design factors should be revised toward reducing emissions.

Student declaration

I, Neale Wardley, declare that the thesis entitled *The Greenhouse Gas Emissions Trading Journey: Finding the Balance between Acceptance, Effectiveness and Emissions Reduction*, is no more than 65,000 words in length, exclusive of tables, figures, appendices, and references. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma.

[redacted]

Neale Wardley 22n December 2020

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List of acronyms

AAU	Assigned amount unit
ABARE	Australian Bureau of Agricultural and Resource Economics
ACCU	Australian carbon credit units
AGO	Australian Greenhouse Office
AOSIS	Alliance of Small Island States
ATU	Allotment trading unit
ARP	Acid Rain Program (US)
BBC	British Broadcasting Corporation
BEA	Bureau of Economic Analysis
CAA	Clean Air Act
CAC	Command and control
CARB	Californian Air Resources Board
CCA	Climate change agreement
CCAP	Climate change action plan
CCTP	California Cap and Trade Program
CCL	Climate Change Levy
CCP	Climate Change Program
CCS	Carbon capture and storage
CCX	Chicago Carbon Exchange
CDM	Clean development mechanism
CER	Certified emission reductions
CFC	Chlorofluorocarbons
CH_4	Methane
CITL	Community independent transaction log (replaced in 2009 by EUTL)
COAG	Council of Australian Governments
COATS	Carbon dioxide allowance tracking scheme
COP	Conference of the Parties (UNFCCC)
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CPM	Carbon pricing mechanism
CPRS	Carbon pollution reduction scheme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CRPS	Carbon Pollution Reduction Scheme
CSAPR	Cross State Air Pollution Rule
DG CLIMA	Directorate General for Climate Action (EU)
EC	European Commission
EDGAR	European Union emissions database for global atmospheric research
EIS	Emissions intensity scheme
EITE	Emissions intensive trade exposed
EMP	Emission monitoring plan

ERA	Early retirement allowances
ERC	Emission Reduction Certificate
ERF	Emissions Reduction Fund
ERMS	Emissions Reduction Market System
ERU	Emission reduction unit
ETS	Emissions Trading Scheme
ETMS	Energy Target Management System
EUA	European Union allowance
EU ETS	European Union Emissions Trading Scheme (later known as the European Union Emissions Trading System)
EUTL	European Union transaction log
ESB	Energy Security Board
GAAP	Generally accepted accounting principles (US)
GDP	Gross domestic product
GFC	Global financial crisis
GHG	Greenhouse gas
HFC	Hydro fluorocarbons
IASB	International Accounting Standards Board
ICAP	International Carbon Action Partnership
IET	International emissions trading
IFRIC	International Financial Reporting Standards Interpretations Committee
INDC	Intended nationally determined commitment
IPART-NSW	Independent pricing and regulatory tribunal of New South Wales
IPCC	Intergovernmental Panel on Climate Change
JI	Joint implementation
KETS	Korean Emission Trading Scheme
kt	Kilo tonne
LTP	Lead trading program
LULUCF	Land use and land use change and forestry
MACC	Marginal abatement cost curve
mmt	Million metric tonnes
NAP	National allocation plan
NEG-ECP	New England Governors and Eastern Canadian premiers
NEPI	New environmental policy instruments
NETS	National Emissions Trading Scheme
NETT	National Emissions Trading Taskforce
NGGAS	New South Wales Greenhouse Gas Abatement Scheme
NGAC	New South Wales Greenhouse Gas Abatement Certificate
NMVO	Non methane volatile organic compounds
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Development and Cooperation

PFC	Perfluorocarbons
PgC	Peta (10^{15}) grams carbon
ppm	Parts per million
RECLAIM	Los Angeles Regional Clean Air Incentives Market
RGGI	Regional Greenhouse Gas Initiative
RTC	Reclaim trading credit
SAP	Sulphur Allowance Program (US)
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
TEEII	Trade exposed energy intensive industry
TNAC	Total number of allowances in circulation (EU ETS)
UK ETS	United Kingdom Emissions Trading Scheme
UN	United Nations
US	United States
US EPA	United States Environment Protection Agency
UNFCCC	United Nations Framework Convention on Climate Change
WCI	Western Climate Initiative
WG	Working Group

Executive summary

The theoretical attraction of cap and trade for policymakers is a reduction of emissions at the lowest cost. In their commitments to the 2015 Paris Agreement on Climate Change 80 countries listed carbon markets as their preferred instrument for reducing carbon emissions (Bayer & Aklin 2020). Haites et al. (2018) found that in 2015, globally there were seventeen ETS operating at both national and sub national levels. In 2019, the International Carbon Action Partnership (ICAP) identified that there were nineteen operating ETS in eleven jurisdictions and another five in the planning stage (ICAPa 2019).

To shed light on the operation of an ETS, evidence is collected from several sources. They include the US ARP, the EU ETS, and the US RGGI. In the initial stages the study was also shaped by the short-lived United Kingdom Emissions Trading Scheme (UK ETS) and the equally short-lived Australian Carbon Pollution Reduction Scheme (CPRS). The UK ETS was merged into the EU ETS and the CPRS was dropped after a change in government. The Californian Cap and Trade Program (CCTP) is introduced to the study to show the impact of earlier experience on a later program.

Increasingly, ETSs are used in parallel with policies such as a mandatory renewable energy uptake. In terms of effectiveness, it is important to consider the different emissions reductions policies that are in place. Other alternative drivers of emissions reduction include technology innovation and human adaptation to climate change.

There is evidence (Narassimhan et al. 2018) that indicates sub-optimal performance within some of the ETS programs. This study compares how three constraints and a set of nine design factors can be aligned to deliver the objectives of the programs. The comparative case study approach taken focuses on defining the key constraints that affect the design of the schemes, i.e., acceptance, effectiveness, and emissions reduction.

The three constraints are drawn from the literature and are explained in Chapter 1, Section 1.4. Taking the comparison to a more granular level, there are nine design factors that underlie the three constraints. These factors are legislation, governance, compliance, rules, compensation, targets, phasing-in, coverage and the distribution of

allowances. The factors were initially identified in the US ARP and the UK ETS, as shown in Chapter 3, Tables 3-11.

The three constraints and nine design factors are treated slightly differently across the schemes that have been studied. The differences reflect how strongly the design factors are aligned to the constraints of acceptance, effective operation and to emissions reduction within a program. A methodology for determining how strongly each factor is aligned with a constraint is described in Chapter 3, Section 3.4, Weighting criteria for the design factors.

Apart from the constraints and design factors used in this study, there are external forces that also shape the schemes over time. In Chapter 7, Section 7.5 briefly considers emissions scenarios under the GFC, and at the time writing, the COVID-19 pandemic.

In relation to the less strongly aligned design factors, these factors have been found, in some cases, to diminish the impact of a constraint. For example, in relation to the constraint of effectiveness, when scheme design is focussed too much the factors of phasing in, compensation and a wide sectoral coverage; effectiveness is diminished.

In the theory of emissions trading systems, a preferred scheme would have wide sectoral coverage, limited free allocation of allowances, stringent targets for emissions reduction, targeted compensation and only a modest phase-in period. Such a set-up is likely to be effective in reducing emissions, partly because the allowances will trade at relatively high prices. However, these high prices will flow through to the users of the products (notably energy) the production and use of which gives rise to the emissions and is likely to generate strong public resistance. By contrast, an ETS scheme with a narrow sectoral focus, a high level of free allocation, modest targets and extensive compensation is likely to be more readily accepted but may have a minimal impact on greenhouse gas emissions.

Program characteristics

The prominence of the various design factors utilised in the study is not consistent across the programs that have been observed. The following section compares similar characteristics identified in four cap and trade programs, it identifies the common factors of coverage, a lowering cap on emissions, allowance allocation, allowance stability reserves and a phased introduction.

US ARP: Start date 1995, single sector coverage, moderate targets and free allowance allocation initially. As the program progressed auctioning of allowances was introduced along with a tighter cap. The US ARP was phased in over 15 years with the 2010 SO_2 cap set at 8.95 million tons, which represented half the level of emissions from the stationary energy sector in 1980. In phase 1 (1995) and phase 2 (2000), there was an annual allocation to a stability reserve of approximately 2.8% of allowances issued. The US ARP continues under the auspices of the Cross-State Air Pollution Rule (CSAPR).

EU ETS: Start date 2005, wide coverage combined with weak targets; in 2006 the EU ETS aimed for annual reductions of 2.33%, subsequently the cap reduced by 1.74% annually to 2020. Initially there was free allowance allocation with limited auctioning. Phase three ushered in auctioning, coverage of chemical production facilities and the European aviation sector. The EC considers that the EU ETS will better the 2015 Paris agreement targets for emissions reductions. As the EU ETS reaches the end of its third phase in 2020 at auction the price of an allowance was €15.15. The EU ETS introduced a stability reserve to manage an excess of allowances that developed in the first two phases of the program.

RGGI: Start date 2009, single sector coverage and moderate targets; in 2009 the RGGI aimed for the stabilisation of emissions; the current cap reduces by 2.5% annually. The RGGI has had up to 90% of allowances auctioned. The board of RGGI Inc. considers that the program is exceeding its greenhouse emission reduction targets. Toward the end of the third control period in 2020 the price of an allowance was around US$5.75. The RGGI uses an upper and lower price collar for allowances with 10% of annual allowances committed to a contingency reserve.

CCTP: Start date 2013, began with medium coverage and initial free allocation then a 5% increase of allowances auctioned annually, cap reduces by 3% annually with phasing in of additional sectors. According to the Californian Air Resources Board, the coverage of the CCTP has increased to 85% of all greenhouse gas sources in the state. During 2019, the California Air Resources Board reported that the CCTP, in conjunction with the Quebec ETS, held the nineteenth joint cap and trade carbon allowance auction and recorded a settlement price of US$17.45 (CARB, 2019). In a similar fashion to the RGGI, the CCTP allocates allowances to a price containment reserve.

Discussion

The US ARP is an earlier Federal government program that, while it targeted only the reduction of SO_2 emissions in the power sector, had strong emissions reduction targets, harsh penalties for non-compliance and limited free allocation. The success of the US ARP supported a theoretical leaning toward the cost effectiveness of emissions trading. In part that success may have been due to the ready availability of reduction options, emission scrubbing technologies and fuel switching to low sulphur coal, for SO_2 emissions. From start-up in the US ARP, the factors that facilitated emissions reduction, i.e. legislation, rules, and coverage (narrow), were considered more important rather than those factors designed to gain acceptance, i.e. compensation, coverage (wide) and legislation.

In contrast, the EU ETS has been characterised by low allowance prices that were a symptom of over allocation of free allowances, designed to gain acceptance. The impact of factors that are included for acceptance rather than emissions reduction distorted the market for allowances in the EU ETS. In the EU, the original targets became redundant in the wake of the GFC.

On the other hand, in the case of the RGGI easily attained targets gained acceptance but limited the emissions reduction capacity of the scheme. Moderate targets were combined with limited free allocation, although the RGGI ultimately followed the example of the US ARP with up to 90% of RGGI allowances being sold at auction.

In both jurisdictions, a process was introduced to manage the allowance price distortions. In the EU ETS, it is known as a stability reserve and in the RGGI a containment reserve. This process is required to remove the surplus of allowances when prices are exceptionally low and release allowances if prices rise unsustainably.

These examples show how each of the schemes managed the acceptance/effectiveness /emissions reduction balance. In the wake of design decisions about the way the constraints and the factors were combined, the programs have either had success (US ARP), been somewhat successful on a small scale (RGGI) or seen as falling short in the early stages, but later (Phase 3) achieving the desired emissions reductions (EU ETS).

In the US ARP, the design strongly leaned toward emissions reduction. In the EU ETS, the balance swung toward acceptance and in the RGGI the initial aim was effective operation. Later schemes now show evidence of learning from these problems, with more attention given to designs that can achieve substantial emissions reductions while maintaining public support. In California, where existing complementary policies are responsible for the bulk of current emission reductions, moderate targets have been introduced initially, with free allowance to electricity distributors to avoid early end-user price rises and encourage acceptance.

The main conclusions of this study are as follows:

1. The greenhouse gas emission trading schemes in the study struggled initially to match the success of the US ARP. Later revisions to the programs have allowed them to get on track to meet or exceed their reduction targets.

2. The designers of an ETS face a choice in how to respond to the constraints of acceptance, effectiveness, and emissions reduction in relation to the calibration of the nine design factors. During the implementation, priority has been toward acceptance in both the EU ETS and the RGGI. This reduced their initial impact in terms of emissions reductions.

3. Setting the balance between the three key constraints and the nine design factors is complicated by alternative policies and by changing economic trends. If alternative policies and a weak economy both work to reduce greenhouse gas emissions, the ETS emissions reductions are diluted. Flexible design elements should preserve the intent of a scheme as circumstances change.

4. A goal for the implementation of future emission trading schemes should be mechanisms that will reduce barriers to acceptance while preserving a strong emissions reduction effect, as is evident in the more recent designs of the CCTP.

Chapter 1: Introduction

1.1 The current greenhouse gas ETS

Initially at least, the greenhouse gas ETSs in the study failed to live up to the expectation that they would be a cost-effective method by which to significantly reduce greenhouse gas emissions. A theoretically preferred approach, the performance of the ETSs that have been studied has shown a slow improvement.

The theory suggests that as emission caps are tightened, and allowances become scarce the affected parties will seek the most economically optimal methods to reduce emissions. The cost effectiveness of this carbon price is what made the process of emissions trading so attractive. There were early doubts about the divergence between theory and practice as greenhouse gas emissions trading struggled to maintain a foothold.

The schemes in this study have persisted and now appear to be matching expectations and a trend shows that scheme mergers are taking place. In the US and Canada regional cap and trade programs share auction activities. In Europe the COVID-19 pandemic offers up obstacles, still the small cap and trade program in Switzerland is integrating with the EU ETS, broadening the pool of trading partners, and the UK has plans to reintroduce its cap and trade program post Brexit.

Measuring the emissions reducing impact of an ETS is complex as many factors other than a carbon price continue to shape outcomes. Notable among the other factors are changes in economic activity such as the global recession in 2007-2008 and at the time of writing the COVID-19 pandemic. Thus, the impact of an ETS on greenhouse gas emissions needs to be separated out from these other factors that may also be reducing emissions.

Several recent studies have attempted the task of attributing emissions reductions. Haites et al. (2018) and Narassimhan et al. (2018) examine up to seventeen greenhouse gas ETSs operating in fifty-five jurisdictions, drawing from the empirical literature. They find that the small programs in New Zealand, Alberta, and Switzerland have had little impact on emissions. In the EU ETS between 2005 and 2012, there was a 4.3% average reduction in emissions across the member states (Narassimhan et al. 2018).

Bayer and Aklin (2020) identify that the EU ETS has on its own removed 3.8% of the EU's total emissions from 2008 to 2016. Their research has found that the EU ETS has reduced emissions beyond what can be explained by the impact of the GFC between 2007 and 2008. They also cite China as a country expected to implement a national emissions trading scheme after 2020.

The studies by Haites et al. (2018) and Narassimhan et al. (2018) both draw on a Murray and Maniloff (2015) paper which found that the RGGI reduced emissions by 24% between 2009 and 2012, demonstrating the power of an ETS scheme. Other applications of cap and trade have demonstrated that the impact on emissions has been modest.

The US ARP is considered by observers to have been a pre-eminent example of emissions trading (Ellerman et al. 1997; Ellerman et al. 2000; Kosobud et al. 2002; Tietenberg 2006; Burtraw et al. 2005; Carlson 2012). The ARP was enacted through the US EPA Clean Air Act (CAA) amendments of 1990, which reduced SO_2 levels to 50% of 1980 levels. The program became binding in 1995 and was aimed at the heat sources of electricity generating facilities. At the start-up of the US ARP, utilities were grandfathered emission allowances (i.e. allowances issued free of charge and based on historical patterns of energy use). As the program developed, the emissions allowances were distributed through annual auctions.

This study has gathered data on several market-based proposals for cap and trade greenhouse gas emissions trading and looks for common problems that have been encountered while implementing these types of schemes. The study seeks to elaborate on the design factors in these schemes that are important to navigate the constraints of scheme acceptance, effectiveness and emissions reduction capacity.

1.2 The case studies in the research

A comparative case study methodology was chosen for the research on greenhouse gas emissions trading. An alternative would be a quantitative approach to establish in detail the levels of emissions that can be attributed to each of the sources participating in a program. It has been found that it can be difficult, due to the alternate policies that exist for reducing greenhouse gas emissions, to distinguish the emissions reductions that are a direct result of cap and trade (Narassimhan 2018; Haites 2018; Hood 2013).

The main comparative case studies are the EU ETS, and the US RGGI. Documentary evidence is the principal source of data as the development of both programs has already been the subject of many other studies. Some other examples of research that has utilised a comparative case study interpretation include Haites et al. (2018), Narassimhan et al. (2018), Creswell (2014), Mora (2010) and much earlier Gable (1994).

Using documentary comparisons and the triangulation of data, a profile is built for each case study using data from open access information repositories. This study is designed to find evidence for how a group of nine design factors that have been identified in other studies interact with the constraints of acceptance, effectiveness and the ability of the programs to reduce emissions.

In the US, market-based instruments such as emissions trading had been used for environmental regulation since the lead trading program (LTP), which began in 1985. In terms of airborne pollutants, the US ARP is one of a few quota systems for atmospheric regulation. The US ARP was implemented to remove SO_2 from the emissions of large stationary energy sources (electric power generators). Given the scale and success of the US ARP, it has been widely thought of as representing a point when 'emissions trading programs went from theory to practice' (Wang et al. 2008, p. 63).

Allowances in the US ARP represent the right to emit one US short ton of SO_2 and were released in annual auctions conducted by the EPA. The participants were also permitted to transfer allowances amongst each other and bank allowances for future emissions. A reduction target timeframe of five years was enforced with a penalty of $2,000 a US short ton of emissions exceeded.

Across each of the case studies, differences come to light regarding the design of a market-based approach. The EU ETS was designed by the European commission (EC), which had opposed the concept of greenhouse gas emissions trading throughout the negotiations for the Kyoto Protocol. The EC reversed its views on this market-based approach and 27 European Union (EU) nations were set on the path of cap and trade greenhouse gas emissions trading.

In the case of the EU ETS, much data has been obtained from the Community Independent Transaction Log (CITL), which from 2009 was known as the European Union Transaction Log (EUTL). In the EU ETS, each participating region had a separate registry that was available in the public domain. The EUTL now holds centralised records that link to a UNFCCC emissions registry.

The case study on the EU ETS covers the first three phases, a 'learning by doing' phase of 2005-2007, the second phase of 2008-2012 (Woolhouse 2008) and more recently material has been included on the current Phase 3 period (2013-2020). Phase 4 of the EU ETS will run from 2021-2030. At the writing of this thesis, the EU ETS covered thirty-three countries.

The case study on the RGGI initially covers in detail the first control period that began in 2009 and covered nine north eastern and Mid-Atlantic States. Data from the RGGI now reaches into the three subsequent control periods up to 2020.

Proposals for the RGGI were developed by the Conference of New England Governors and Eastern Canadian Premiers (NEG–ECP). The history of this lobby group can be traced back to the 1800s. The RGGI was developed from what was known as the climate change action plan (CCAP). The CCAP emerged from a meeting of the NEG-ECP in 2001. At the time, the American states seeking to participate in the RGGI were New England, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

The Canadian provinces that were involved in developing the climate action plan but did not at the time join the RGGI were, New Brunswick, Newfoundland, Labrador, Nova Scotia, Prince Edward Island and Quebec. In terms of scale and size, the EU ETS and the RGGI vary considerably, with the RGGI having fewer participant types (industry sectors) and overall numbers of participants.

In the case of the RGGI, and in accordance with the guidelines of the incorporated body, RGGI Inc., participants are required to submit emissions data in line with the regulations imposed by the states themselves. The reporting from the states is guided by US Environment Protection Agency (EPA) regulations (40 CFR Part 75) and transferred to a RGGI CO_2 Allowance Tracking System (COATS). The RGGI emissions data is publicly available from the COATS.

The participants in the RGGI were initially bound to a three-year compliance period. This means that first the formal accounting of surrendered allowances took place in 2012. To achieve compliance, the total number of submitted allowances should correspond with emissions of CO_2 in the time between 2009 and 2011. Any allowances that are excess to the requirements of a participant could be carried over into the next control period. Material from the subsequent RGGI control periods 2, 3 and 4 is now included in the study.

1.3 Research questions

The three research questions that follow seek to firstly, interpret the influence that a successful predecessor trading scheme, the US ARP, has had on subsequent trading programs for the greenhouse gases. The second research question seeks to find out if the constraints and design factors of the schemes are aligned similarly and assess how any differences have affected overall performance. While thirdly, the study asks if the ability of an ETS to achieve large scale, cost-effective greenhouse gas emission reductions has been hobbled by the acceptance factors. The three research questions are shown below.

1. How have the lessons from the US ARP been translated into the later programs for greenhouse gas emissions trading?
2. Do the constraints and design factors used in the study align in a similar fashion across each of the case studies and what is the impact of any differences?
3. Can it be shown that the factors aligned with acceptance of an ETS may reduce the schemes ability to mitigate greenhouse gas emissions?

1.4 Key terms in the research

The study differentiates between three constraints that form the central theme of this comparative study. These are the constraints of acceptance, effectiveness and emissions reduction, these constraints are defined below. The three constraints are underpinned by a group of factors that feature in the tradable permit literature and data from the greenhouse gas programs studied. The nine ETS design factors are legislation, rules, coverage compliance, targets for emission reductions, allowance allocation, governance, phasing-in and compensation.

1.4.1 Acceptance

Acceptance of cap and trade in this study refers to the ongoing support for legislation that must be enacted by the elected representatives of a community. Concerns about the impact of emissions trading on an economy are reflected in the emission reduction targets, how the initial allowances are allocated, and scheme coverage. In Australia, it has been suggested that there was a lack of consultation regarding the methods that could be used to reduce emissions of the greenhouse gases. This in turn led to a diminished level of community acceptance of greenhouse gas emissions trading (Parkinson 2010; Akter & Bennett 2009).

In the design of the Australian scheme known initially known as the CPRS, there was a focus on the impact of price rises on the community. Energy producers flagged the flow on effect of pricing carbon and the groups described as emissions intensive and trade exposed, predicted their competitive position would be severely impacted. A carbon tax was introduced under the Clean Energy Act of 2001, and a tonne of carbon price signal emerged, $23.00 over 2012-2013 and $24.15 during 2013-2014. The carbon tax did achieve emissions reductions, although the Australian carbon tax did not make the transition to an ETS as it was revoked in 2014.

In jurisdictions that are inextricably linked to energy from fossil fuels, the mitigation of greenhouse gas emissions by a cap and trade ETS imposes a considerable economic burden. This is why a variation on emissions trading has been used as an introductory measure, it is known as base line and credit.

In the baseline and credit design, an upper limit for greenhouse gas emissions are set and the governing body issues free allowances for emissions up to the limit. Allowances for emissions beyond the baseline must be purchased. Narassimhan et al. (2018) identify that the baseline and credit scheme is more acceptable to economies with a relatively high emissions intensity.

Acceptance has also been framed by Haites et al. (2018), in terms of stakeholder engagement. They identify that acceptance can be enhanced by the level of public involvement in the ETS rule making process. They suggest that regular stakeholder meetings to receive public comments on major rule changes meant that the RGGI fared well in the building of constituency support.

Haites et al. (2018) cite Oh, Huon and Kim (2016, p. 17) in the example of the Korean ETS (KETS) where an Energy Target Management System (ETMS) was negotiated to give firms some initial experience with the monitoring and verification of emissions data. It is suggested that the KETS is an example of the benefits of early engagement with stakeholders.

In this study, the constraint known as acceptance reflects a position where most of members of a government firstly, believe the science about climate change and the contribution of anthropogenic greenhouse gas emissions to global warming. Secondly, that a workable agreement can be struck between diametrically opposed sections of the duly elected representatives in parliament, supporting the use of a market-based mechanism. Any such agreement must have passed the test of potential participants, including energy intensive industries, large corporations and the stationary energy sector.

The design factors that are more strongly aligned to the constraint of acceptance are introduced to ameliorate the harsh economic impacts of the other two constraints of effectiveness and emissions reduction. If a market-based mechanism is to be accepted, a trade-off is usually employed in terms of the flexible parameters of a scheme.

This trade off can be in the form of compensation (the free allocation of permits) and a slow phase-in of a scheme. The phase-in period extends the reaction time for participants, and regulators of an ETS and therefore helps in terms of acceptance. It is acknowledged that the first years of an ETS are a pilot phase in which there would be lessons to be learnt.

In California, the CCTP was less focussed on acceptance, in the US there had been long experience with market-based mechanisms for the reduction of several other air borne pollutants. Compensation in the CCTP was in the form of redistribution of the funds that were raised in the permit auctions. Acceptance was enhanced by support for consumers through subsidy toward electricity bills and the uptake of renewable energy.

1.4.2 Effectiveness

The Kyoto protocol of 1997 proposed what was a controversial approach called greenhouse gas emissions cap and trade, the EU initially opposed cap and trade while the US on the other hand supported the idea. Subsequently only a handful of untried designs developed for the new environmental control instrument, i.e. greenhouse gas ETS. As a result, the governance and compliance measures that emerged for both the EU ETS and the RGGI were based on limited practical experience. As a result of the challenges associated with executing cap and trade and the limited practical experience, effectiveness, in this study, relates to how well a program meets its' ongoing operational requirements, e.g., managing the compliance of the participants.

In terms of effectiveness, market-based programs for reducing CO_2 using greenhouse gas emissions trading can be judged by their ability to administer the schemes and to monitor emissions in the targeted sectors. While specific activities within the schemes vary with regional and legislative differences, Ellerman (2005) identified some characteristics of an effective tradable permit system. Characteristics that relate to the transferability of allowances, the methodology for the distribution of those allowances, the emission cap that is applied and the measurement of emissions. Another fundamental item involves defining the pollutants that are covered by the scheme which in turn defines the sectors covered.

The development of programs for emissions trading follows, according to Tietenberg (2006), a general pattern that is the basic framework of an emission trading scheme, i.e., a dialogue between two parties. Tietenberg elaborates, that in this dialogue, the first party (a regulator) determines the mode of governance, sectoral coverage, and other parameters of a scheme; the second party (the source of the greenhouse gases) make decisions about an optimal response to a new set of rules.

Haites et al. (2018) have identified a price signal and price stability as another dimension of effectiveness. Measures have been taken in the past to control price volatility through a reserve or price collar. A containment reserve takes allowances out of the market to maintain scarcity, or releases allowances when prices are high. A collar operates to set a floor price (minimum) and a price ceiling (maximum) for allowances.

1.4.3 Emissions reduction

A tradable permit program is quantity based, e.g., tonnes of CO_2, rather than a price based, i.e., taxation, method to reduce emissions. It has been argued that an environmental tax and a tradable permit program are fundamentally the same thing. From an economic perspective, the attraction of trading is allowing the sources of the emissions to make decisions about the lowest possible compliance costs (Stavins 2001; Tietenberg 2003; Ellerman 2005).

When this study was designed, it was acknowledged that transparent and accurate measurement of greenhouse gas emissions could occur at the individual facility level. This allows emissions reductions in the study to be assessed on an annual basis from scheme start to the present time. The EU ETS has often expressed emission reductions in terms of a 1990 baseline. The UNFCCC adopted a 2005 baseline in a recent round of commitments from countries party to the Kyoto protocol.

In Australia, greenhouse gas emitting facilities are required to regularly report to the Australian Greenhouse Emissions Information System which is currently under the Department of Industry, Science, Energy and Resources. Similar arrangements are in place for the other regions in this study, who since 2003, have passed this emissions data on to the UNFCCC as part of the National Inventory Submissions.

So the principles of accounting for greenhouse gas emissions are now well established. The factors in the study that are strongly aligned to emissions reduction are elements like governance, rules, and compliance. These factors reflect the legislative processes that are established accepted accounting principles where there is little or no room for adjustment; unlike other more variable factors in the study such as coverage, targets, compensation, and a phased introduction.

In the greenhouse gas cap and trade programs in this study, each participant must have a permit for each tonne of CO_2 emitted (or short ton in the RGGI program). In a cap and trade program in the meeting of the targets for emissions reduction, there are three possible outcomes for each facility. One, the facility has for the period covered emitted less than the target level. Two, the facility has met the target level. Three, the facility has not been able to reduce emissions to the target level.

For outcome one, there are an excess of permits that are available for banking, selling or carried over to the regulators reserve. For outcome two, no action is required. For outcome three, facilities that have not been able to meet the targets must purchase permits or pay a penalty for non-compliance.

In this study, the emissions reduction of a program for cap and trade are defined as those aggregate reductions that can be directly attributed to each source participating in that program.

Typically, the targets for emissions reduction (emission caps) and the actual centrally reported emission reductions in programs such as the EU ETS and the RGGI relate to aggregate levels of emission reductions. The publicly available individual facility level data has been used in the first part of this study to discuss emissions reductions. In the later parts of the study, more readily available aggregate data has been made available from the regulating authorities and developed by research into emission patterns.

Some observers are concerned that in a region covered by an ETS the total level of emission reductions is influenced by alternate policies, e.g., renewable energy targets.

> Emissions reductions achieved by an ETS can be measured by the change in actual emissions covered by the ETS (Haites et al. 2018), but it is difficult to directly attribute these results to the ETS in jurisdictions with other complementary emissions-reduction policies. The endogenous and simultaneous nature of interaction between complementary policies such as feed-in tariffs or energy efficiency performance standards, and the ETS, makes it difficult to

estimate the net impact of an ETS on overall emissions reduction (Hood 2013). (Narassimhan et al. 2018, p. 7)

Critics of greenhouse gas emissions trading hold the view that the targets for emission reductions are inadequate for the desired environmental outcomes (Walters & Baird 2009). About emissions trading programs generally, there has also been a concern about the polluters being given the right to pollute at a price determined in an unproven marketplace (Pearce 2003; Beder 2009; Pearse 2010). This study has observed both the push for and resistance to the choice of tradable permits as an alternative to an environmental tax or government applied command and control (CAC) measures.

1.5 Context of the research

The disparity between emission reductions in the programs that have been designed for the greenhouse gases and the ongoing reduction of SO_2 in the US ARP, which became the ARP–CSAPR, provide the context for this study.

The conversation in the literature about tradable permit programs has a subset for greenhouse gas emissions trading. Due to the large-scale problem of global warming, greenhouse gas emissions trading has been put forward as a cost-effective response (Haites et al. 2018), ahead of control and command (CAC) measures and carbon taxes. The focus of this study is the relationship between the constraints of acceptance, effectiveness and emissions reduction and their interaction with the various design factors that affect the greenhouse gas emission trading.

It is said that greenhouse gas emissions trading can be used to introduce a right to pollute through an allowance price on the emission of one tonne of CO_2 or CO_2e (Ellerman, 2005). The price on carbon becomes binding when a governing body places a cap on the levels of emissions that are allowed. An allowance needs to be surrendered for every tonne of CO_2 or CO_2e that is emitted; and beyond the cap, a fine applies.

The price of these transferable allowances, that can be banked, bought, or sold, reflects the marginal cost of abatement of the greenhouse gas. As emission caps become binding, then it is believed that investment in marginally more expensive fossil fuel technology will be less attractive, while investment in the next marginally less expensive low emissions technology or renewable energy will become progressively more attractive. This price-based replacement theory has been tested and proven in many regions where wind turbines and solar farms are now proving a cost-effective replacement for fossil fuels, even where no ETS exists.

Haites et al. (2018) have found that from the time this study began, more than a decade ago, that the number of operating ETSs has increased steadily. Their research indicates that while an ETS and a carbon tax can provide emission reductions, the reductions, especially in the case of a carbon tax, are not guaranteed. Narassimhan et al. (2018) observe that there is significant revenue raised by the auctioning of allowances and that emissions reductions in an ETS may be overshadowed by the re-investment of these ETS dividends in alternative emission reduction activities.

1.6 Conceptual framework for an ETS carbon market

The study covers a cap and trade emissions trading regime, where greenhouse gas emitters are required to purchase allowances equivalent to their emissions while staying within prescribed emissions limits (targets or caps). Both main greenhouse gas case studies in the research, the EU ETS and the RGGI, have provided blueprints for the development of a carbon market. The ambitious design of the EU ETS has been the focus of the conceptual framework for the development of an emerging carbon market, shown below in Figure1.

In developing the framework, four design factors were identified as prominent at the start-up of a carbon market. These factors are the level of the caps or targets, the gradual phase-in, extent of the scheme's coverage and the way the all-important allowances are distributed.

Taking for example the allocation of allowances in the EU ETS, the development of primary and secondary markets for allowances has been observed. The primary market is for the annual distribution of allowances, each participant in a cap and trade scheme must surrender an allowance for each tonne of CO_2 or a CO_2 equivalent that is emitted. Experience has shown that a secondary market for these tradable allowances develops as some participants can more easily reduce their emissions. In this secondary market, non-complying entities that exceed their allocation, can purchase allowances for the reconciliation of emissions.

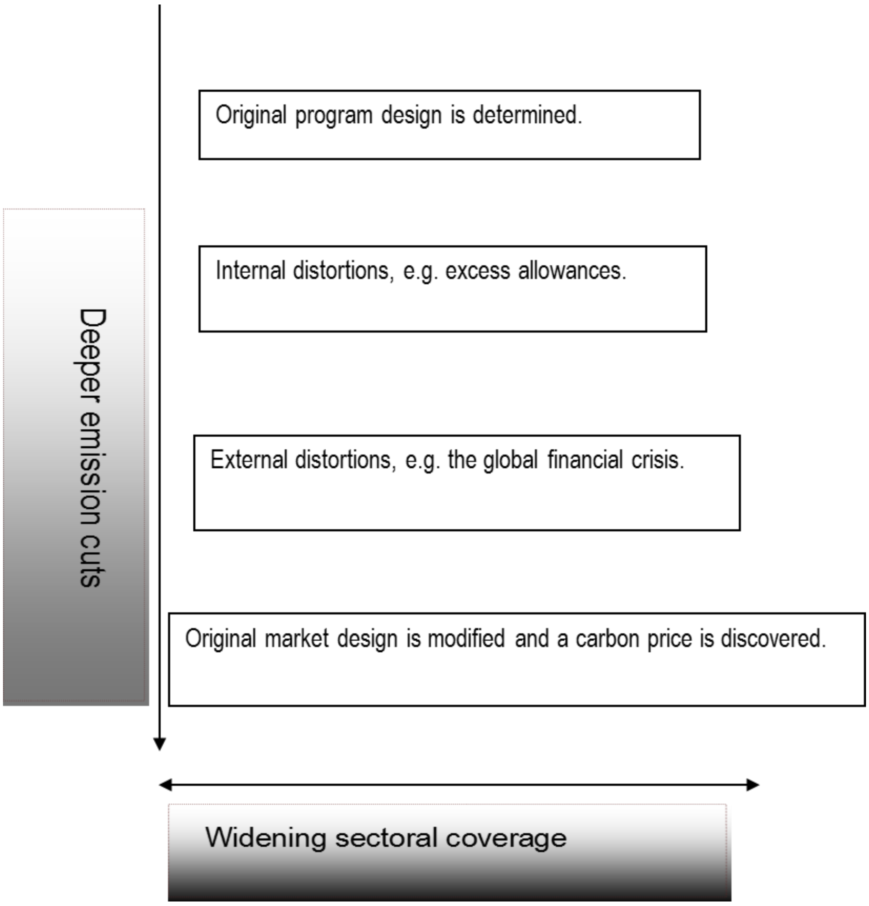

Figure 1: Conceptual framework

A third market is the offset market in which the certified equivalent of a greenhouse gas reduction, e.g., energy efficiencies or carbon sequestration becomes tradable in a market for carbon offsets. The suite of greenhouse gases are CO_2, CH_4, N_2O, sulphur hexafluoride (SF_6) hydro fluorocarbons (HFCs) and perfluorocarbons (PFCs) all these gases can be represented as an equivalent of one tonne of CO_2.

The conceptual framework shown below was developed in a period when there has been a high level of interest in the possibilities offered by greenhouse gas emissions trading. In practice, the several stages shown in the framework have subsequently evolved in the real time carbon markets.

These developmental stages describe the original design, initial changes to the original design, external forces that result from further distortions and eventually the discovery of a carbon price in the emerging markets. This conceptual framework has been shaped by the introduction of pilot schemes for greenhouse gas emissions trading. It is anticipated that the later stages of the conceptual framework for an emerging carbon market will be associated with wider sectoral coverage and deeper emissions cuts.

When the EU ETS entered phase three during 2013, the program had been running for a decade. The first two phases of the EU ETS (2005-2007 and 2008-2012) served slightly different purposes. The first three years were an introductory phase and the constraints associated with acceptance were important. The following four years saw the factors related to effective operation and emissions reduction within the program become more refined.

1.7 Organisation of the thesis

The body of this thesis consists of eight chapters. Chapter 1 provides an overview of the practical application of greenhouse gas ETSs, introduces the case studies and provides definitions for the key constraints and design factors. The chapter introduces the three research questions that were developed for the study.

A review of the literature is the focus of Chapter 2. This chapter briefly discusses climate change and environmental regulation using a market-based approach and tradable permits. Also discussed in Chapter 2 are similar comparative policy studies, carbon taxes and the Australian response to climate change. Chapter 2 concludes with a discussion about some limitations of the study.

Chapter 3 provides a discussion on the methodology for the collection of data to answer the research questions, gives examples of related research and describes how the material in the study is used to find the degree of alignment each of the design factors have with the constraints used in the study.

Chapter 4 considers the transfer of knowledge from the US ARP. The chapter also considers the concept of a carbon tax and the impact of alternative policies for emission reductions.

Chapter 5 covers the case study on the European Union emissions trading system (EU ETS). Chapter 6, in a similar fashion, covers the case study on the United States regional greenhouse gas initiative (US RGGI). Chapter 7 draws together the information on the two main CO_2 case studies in a comparative manner.

Chapter 8 concludes the thesis by answering the research questions and summarising the important elements of the study. Differences between the case studies, limitations, directions for future research and innovation are also discussed. The references, appendices, and a glossary of frequently visited websites end the thesis.

1.8 Chapter summary

Chapter 1 introduces the problems that need to be solved and asks have greenhouse gas ETSs learnt from the prior experience with tradable permits in the US ARP. The chapter introduces three constraints and nine design factors used as the metrics of the study.

The UNFCCC has guided the introduction of, among other things, a market-based response to greenhouse gas pollution. Its hopes were pinned on tradable permits, or cap and trade greenhouse gas emissions trading. The study seeks to establish if the alignment of the factors with the constraints has hindered the greenhouse gas ETSs in achieving what they set out to do.

Large scale greenhouse gas emissions trading is a complicated process and the bodies governing the process had limited practical experience. Some evidence has been found for the required regulatory structures for greenhouse gas emission trading in various regions. This research has found evidence for some of the internal forces that shape policy toward the design of carbon markets. There is also evidence presented for the external forces that shape policy about trade between facilities and, in some cases, across national borders (Cooper et al. 2011; Wang et al. 2008)

If an effective cap on emissions was to lower appreciably, then the trade on any existing carbon markets may well increase in proportion (Bernstein 2010). This activity in the market could coincide with higher energy prices, which in turn has the potential to stimulate capital investment in the, now affordable, alternatives to fossil fuel energy.

In the literature review chapter that follows, evidence is found for a framework that describes the important design elements of greenhouse gas emissions trading. The framework includes factors that are determined to have an important interaction with the key constraints of acceptance, effectiveness and emissions reduction. The literature review also examines the prior markets that have developed for tradable permits.

Chapter 2: Literature review

2.1 Introduction to the literature review

In real time, we are witnessing the catastrophic effects of global warming, fires on an unprecedented scale, slowly deepening glacial melts and the demise of fossil fuel technology that provides prosperity but has pushed us to the brink. The literature review initially takes a step back to take a look at the difficult emergence of the Kyoto protocol to tackle global warming that is driving an enhanced greenhouse effect (BOM 2003).

The portion of the literature review that follows then covers the prior research on price-based regulation of the environment using tradable permits. This study has been conducted over a lengthy period and this reflects the evolutionary nature of the processes to mitigate the greenhouse gases. in this regard the UN IPCC suggest, "that climate change decision making is not a once-and-for-all event, but an iterative risk management process that is likely to take place over decades, where there will be opportunities for learning and mid-course corrections in the light of new information" (Fisher et al. 2007, electronic text, Chapter 3, Section 3.5.1, p. 225).

The literature review consists of ten sections. Section 2.1 introduces the literature review. Section 2.2 provides historical information on the global response to the climate change; Section 2.3 provides a background on tradable permits. Section 2.4 follows the development of greenhouse gas emissions trading. Section 2.5 relates to the key elements of emissions trading. Section 2.6 considers the design of prior programs. Carbon taxes are discussed in Section 2.7. Sections 2.8 and 2.9 consider Australia's historical position in terms of global emissions and a stilted conversation about the market-based approach. Section 2.10 considers limitations of the literature review and provides a summary of the chapter.

The literature review seeks to investigate the increasing interest in market-based methods by which greenhouse gas emissions may be mitigated. As a result, the following areas of study were considered fundamentally important: climate change, tradable permits, environmental taxes and the pilot schemes for greenhouse gas emissions trading.

From a methodological perspective there are examples in the literature of similar comparative policy analysis and case study methods around environmental regulation. The literature review provides examples of the case study approach that underpins this research (Boemare & Quirion 2002; Aldy, Barrett & Stavins 2003; Oikonomou & Jepma 2008; Ash 2010, Schamalensee & Stavins 2013 & 2015; Narassimhan et al 2018). The literature review also provides examples of how secondary data has been obtained through archives, research documents and publicly available databases (Yin 2003; O'Leary 2004; Borghesi & Montini 2016; Haites et al 2018; Bayer & Alkin, 2020).

2.2 Climate change and the Kyoto protocol

In Rio de Janeiro during 1992, the UN held an earth summit where over 160 countries signed an atmospheric compact and the number of signatories gradually grew to 182 countries by 2001 (Ekins & Baker 2001) and then 187 countries in 2003 (Aldy, Barrett & Stavins 2003). In 2012, the parties listed as signatories represented around 64% of global greenhouse gas emissions.

The compact came to be known as the UNFCCC and came to represent over 190 signatories (UNFCCC 2014b). The UNFCCC is a multilateral agreement that initially sought to stabilise the global level of greenhouse gases to a 1990 baseline. It was a complementary process to the 1987 Montreal Protocol that produced tangible results toward eliminating the ozone layer depleting gases such as chlorofluorocarbons (CFCs) (Breidenich et al. 1998; Luken and Grof 2006).

In 1992, industrialised countries were responsible for around 90% of accumulated greenhouse gas (Grubb 2000). It is indicative in policy making for the Kyoto protocol that the north-south inequities were a formative influence on the Kyoto flexible mechanisms of Joint Implementation (JI), the Clean Development Mechanism (CDM) and greenhouse gas emissions trading. While the more developed, or northern, economies have been asked to show leadership, their relatively high abatement costs may lead to a transfer of investment and leakage of emissions to the lower abatement costs of a developing, or southern, economy (Aldy, Stavins & Barrett 2003).

Breidenich et al. (1998) and Cline (1991) suggested that developing countries could jeopardise their long-term economic standing by undertaking alternative technology and switching fuels. Transitional alternatives for developed economies include a hybrid scheme based on taxation and tradable emission permits.

The significant anthropogenic greenhouse gases are carbon dioxide, methane and ozone. Natural cycles are responsible for the most prolific greenhouse gas, which is water vapour. For several decades it has been held that global warming is linked to anthropogenic activities, particularly the burning of fossil fuels. These activities contribute to an accumulation, within earth's atmosphere of the greenhouse gases (Haughton 2004; Bolin 2006).

There has been doubt about the reliability of long-range forecasting in terms of global climatic trends. Recent extreme weather events around the world underpin the global warming trend. Data collected for this study assists with the amelioration of early concerns about the economic modelling of a price based abatement processes (Stone 1992; McKibbin & Wilcoxen 2002). The early reports also expressed concern about asymmetrical information produced from the modelling which would lead to inefficiencies in the markets that support an ETS.

It has been observed that the complex administrative challenges of a coordinated international price driven environmental management process, such as emission trading, require a high level of trust and sharing of information between participants. Bailey and Rupp (2004, p. 237) stated: "Recognising that the increasing complexity of environmental issues militates against their resolution by individuals acting in isolation".

Boehmer-Christiansen (2003) suggested that there is an economic inequity between the burden that the governments of the developed and developing countries must share. While the interests of established energy intensive industries are proving to be a barrier toward change that will hit coal-based economies like China and Australia hardest. As a result of large workforces facing redeployment, politicians are subject to socioeconomic pressures in their policy making.

Boehmer-Christiansen suggests that this is to the detriment of the political process and encourages sub-optimal solutions. This is particularly the case for developing economies that may be subject to the incompatible interests of the more advanced technical, commercial, and political regions. This conflict reflects the so-called north (developed economies) versus south (developing economies) divide.

At Kyoto, COP 3 released information that suggested a market-driven response was appropriate and that it should include in its design two credit programs, JI and the CDM. Also, one which is a cap and trade system described then as "a provision for cost-effective implementation through a set of tradable permit mechanisms" (Hahn & Stavins 1999, p. 286).

It was also decided that for the Kyoto protocol to come into force, fifty-five countries needed to sign. This would account for fifty-five percent of the 1990 emissions of the 1992 UNFCCC signatory countries. Breidenich et al. (1998) suggested that there was robust but fruitful debate in the lead up to an agreement at Kyoto.

The UNFCCC conferences that were to follow were not characterised by this success. Following COP 3 (Kyoto 1997) the subsequent meetings of COP 4 (Buenos Aires 1998) up to and including COP 19 (Warsaw 2013) were not able, as was envisaged, to move progressively toward a substantive binding international agreement.

Extensive literature is now available for the purposes of research into environmental economics and climate science. While the established economics literature provides a background on tradable permits, the international coordinating body for data on global climate change has been the IPCC. The IPCC has operated three working groups (WG) that report on the direction of research.

The IPCC working groups produce four main reports, including an update on the overall state of the enhanced greenhouse effect in the synthesis report, which incorporates the three other reports. These three reports are: the physical science basis report (working group one); the impacts, adaptation and vulnerability report from (working group two); and the mitigation of climate change report (working group three). It was in the working group three report where Metz et al. (2007) introduced linkages to emissions trading theory.

The Kyoto protocol acknowledged that sovereign nations would, at least, need wide autonomy to design domestic schemes to achieve their emissions targets. The protocol also embraced emissions trading, along with JI and CDM, as part of a cost-effective approach. It was also envisaged that these domestic schemes could be based on a combination of a carbon tax and a cap and trade program (Hahn & Stavins 1999). The challenges of implementing programs such as these were included in the discussions at the UNFCCC COP 6 at The Hague in the Netherlands. A significant US and EU rift developed during these climate talks in 2000. International negotiations stalled as the various positions became increasingly separated.

Views from the US representatives and members of the EU delegations had become polarised around many issues, including the provisions for carbon sinks and linking to the CDM. The US considered that it "could be forced by international pressure to deliver something that is politically impossible on the timetable remaining" (Grubb & Yamin 2001, p. 271).

Grubb and Yamin (2001) saw the unprecedented scope of the negotiations that were undertaken at COP 6 as a precursor to the failure of talks. In their opinion, COP 6 inevitably collapsed under the weight of a:

> …hugely complex agenda spanning new institutions for multilateral finance and technology, the operation of the unprecedented Kyoto mechanisms for international emissions crediting and trading, a range of compliance issues, carbon sinks, adaptation to climate change, commitments to minimize potential adverse consequences of mitigation, especially for oil exporting countries, and much more. (Grubb & Yamin 2001, p. 266).

Despite the potential impasse as a result of the US (and Australia) distancing themselves from the Kyoto Protocol (Saeverud & Wettestad 2006; Den Elzen & de Moor 2002), by the end of 2001, the process had restarted in Marrakech and countries continued to ratify the Protocol, which included a workable implementation of the flexible mechanisms of JI, CDM, and domestic emissions trading (Clemencon 2008; Convery & Redmond 2007). Four years later in 2005, 141 countries had ratified the Kyoto Protocol, thus bringing it into force (UNFCCC 2005; BBC News 2005).

Australia eventually chose to ratify the Kyoto Protocol in Bali during 2007, adopting a target of 108% of 1990 levels for greenhouse gas emissions (Productivity Commission 2008). At this time the scientific evidence supported the environmental and economic concerns relating to the effects of human-induced climate change (Sathiendrakumar 2003; NETT 2007).

In relation to framing an ongoing response to climate change, there is a body of literature that discusses whether, as in the past, the UNFCCC will be able to develop a successor to the Kyoto protocol (Pandey 2014). At the time of writing, the UNFCCC remains central to a coordinated response that seeks to obviate the threats posed by global warming. An extension of the first compliance period of the Kyoto protocol was undertaken in 2012.

In Paris during 2015, the UN hosted the twenty-first annual climate change conference, known as COP 21. Previous COP meetings have been plagued by the difficulties encountered in reaching a meaningful consensus. It had been foreshadowed that new strategies for the establishment of broad greenhouse gas reduction targets may not emerge from the COP meetings (Grubb 2011).

The commitment of the UNFCCC parties, between 2013 and 2020, was to an 18% reduction of the 1990 levels of CO_2e and CO_2 in the atmosphere. A series of UNFCCC conferences of the parties had little success in reaching international agreement on coordinated action. In 2015 the UNFCCC had established commitments to emissions reductions in the form of intended nationally determined commitments (INDC).

There has not been, yet an agreement reached on the parameters of a coordinated international greenhouse gas abatement process. The IPCC has identified that action on climate change requires an intergenerational approach and it is estimated that up to 90 years (or three plant life cycles) may be required to institute the replacement technologies for fossil fuel-based energy production.

At COP 21 held in Paris in 2015, the agreed aim was to keep the average temperature increase to between 1.5°C and 2°C above pre-industrial levels. Some consider that the commitments in the 2020 to 2030 INDCs are not adequate to achieve this temperature limit (Meinshausen et al. 2015; Schleussner et al. 2016).

2.3 Tradable permits

In the seminal discussion about market-based environmental regulation, contrary arguments were developed by Arthur Pigou in the 1920s and Ronald Coase in the 1960s. One aspect that emerged has been described as a Pigovian tax regime. This recognises that the damage from an undesirable externality, such as smoke, could be compensated for through a tax. Coase, however, considered that this type of government intervention (i.e., a tax) was inefficient when the free market could determine the social cost.

In relation to government intervention through command and control or a carbon tax, Coase (1960, p. 42) said that such a subjective approach “bristles with difficulties” and that the process of command and control, or a tax on pollution, does not ensure the highest possible value placed on the externality of pollution. In contrast, in a market of tradable permits, where the right to pollute is a factor of production, the social cost would be reflected in a more accurate fashion.

Following the set of emissions trading models that were designed in the sixties by Crocker (for air pollution), and Dales (for water pollution) (Goulder 2013 & Ellerman 2005), it was Baumol and Oates (1971) that theorised the relative efficiency of tradable permits when compared to a tax. They put forward a process for tradable permits that applied a charge through a market mechanism to abate an undesirable externality and to achieve, it was hoped, an improved environmental outcome (Naughton 1994; Shields 2007; Tietenberg 2006).

In terms of air pollution and emissions licensing charges, Montgomery (1972) found that a cost minimisation problem could be solved and that a market-based method was superior to taxation. As the total cost to the firm could only be determined by the operators of a facility and not a government regulatory body, then “The market makes the necessary calculations independently in the course of reaching equilibrium. For this reason, we are led to consider licensing schemes as superior to taxation” (Montgomery 1972, p. 411).

Montgomery had provided a theoretical platform from which the emissions trading process could be appreciated, although Stavins (1998) observed that it had not been adopted widely as a regulatory form of control. Montgomery introduced the idea that air borne pollutants could be substituted between one source of the pollutant and another allowing for flexibility in terms of accounting for the way emissions were counted.

In the 1988 book by Baumol and Oates, *The Theory of Environmental Policy*, it is said that there are advantages in marketable permits over fees (or taxation). First, a tradable permit system reduces uncertainty about the price of the right to pollute. Secondly, continuing inflation tends to reduce the value of a fee; and thirdly, that emission allowances or "systems of pricing incentives promise large savings in aggregate abatement costs" (Baumol & Oates 1988, p. 178).

Hahn and Hester (1989, p. 363) stated that in a competitive market for environmental permits, where firms seek the lowest cost of production, "the overall cost of achieving the environmental standard will be minimized". Similarly, Noll (1982, p. 121) suggested that polluters, through capital investment decisions, can "minimize the sum of abatement costs and permit expenses".

Baumol and Oates (1988) extended the analysis between the marginal benefit and marginal cost of limiting a damaging externality (of pollutants in air or water) by using either a tax regime or tradable permits. Their propositions were made from the position of a regulator who had to apply a tax estimate for the cost for abatement (i.e., an educated guess that is likely to be lower or higher than optimal). As a result, emitters can pay too much in abatement costs, or externalities are not limited sufficiently, and it was found that "the system of marketable permits is the preferred policy instrument" (Shrestha 1998, p. 503).

The underlying reasoning for a tradable permit system was that firms seeking the lowest costs of production, and operating within a competitive market for environmental permits, will achieve the prescribed emission targets most efficiently (Hahn & Hester 1989). In this context, the sources of the pollutants would trade emission rights "to correct undesirable externalities from production or consumption" (Noll 1982, p. 120). The tradable permit process was thought to apply the greatest cost to those sources with the "higher marginal impacts on the environmental target" (Tietenberg 2008, p. 4).

The suggestion was that a market was feasible if it gave license holders a right to pollute and to trade that right. Montgomery provided the mathematical proof in a series of functions that described, among other things, the maximum profit available at a fixed level of emissions. He also provided the relative cost of adopting a fixed level of emissions, which was defined as the difference between the maximum level of unconstrained profit and the maximum level of constrained profit.

Montgomery felt that there were three techniques that could be used by a source to meet the fixed emission levels: "by reducing the scale of output, or by altering the product mix of the firm. Second, the production process or the inputs used, such as fuels, can be altered. Finally, 'tail end' cleaning equipment can be installed" (Montgomery 1972, p. 399).

In 1989, Hahn and Hester provided insights into both the benefits and the difficulties in using marketable permits in environmental regulation in the US. Their normative research sought to provide a standard in relation to the cost-effectiveness of the tradable permit approach. Their deliberations also contained positive research that used the data from prior programs to examine the behaviour of various market-based approaches to the abatement of emissions.

The Pigovian tax-based approach has attracted some criticism because it requires guesswork by policy makers in the application of the taxes. This guesswork can be carried out in an iterative fashion or in accordance with the appraised social cost and environmental damage caused by emitters.

This study acknowledges a long-standing economic debate around the choice of a Pigovian tax (intervention by government) to compensate for pollution and on the other hand a market orientated Coasian approach. The application of either of these two approaches to the pricing of emissions by either a price-based approach (taxation), or a quantity-based approach (tradable permits), is very similar. Some (DeSerpa 1993; Hovenkamp 2009; McKitrick 2011) consider that the theories of Pigou and Coase tend to meet at a point where the economic efficiencies of a tax equal those of a trade in permits.

Several emission mitigation schemes have been designed and driven by market mechanisms in the US. Two significant programs, in terms of this research project, were the LTP, which was considered in some detail by Hahn and Hester (1989), Naughton (1994) and Tietenberg (2006), and the US ARP (or SAP), which has been discussed by Stavins (1998), Hahn and Stavins (1999), and Nye and Owens (2008). These studies provide a general entry point into understanding the tradable permit process.

The US government, via the US EPA provided the legal grounding for federal programs to address air pollution in the CAA of 1970 (USEPA 2008). Later amendments to the CAA in 1977 were the catalyst for an early ETS. A feature of the CAA that aimed to stimulate economic activity was called the offset policy. This was introduced in 1979 and allowed new or existing emitters in an area to trade ERCs with establish operations in the same area (Tietenberg 2006).

Tietenberg suggested that the CAA also responded to economic efficiency concerns through the development of several other features, which became known as bubbles, netting, and banking. A bubble allowed for multiple existing sources, with emission rights allocated to the same owner, to be treated as though they were in a bubble. So, rather than linking emission rights to a source, they could be spread over several sources within the bubble.

Netting allowed for the expansion or modification of existing facilities to bypass the more stringent rules that would apply to new facilities requiring additional permits. Banking allowed emitters to store ERCs for use at some later date (Naughton 1994). The decision by the US EPA to allow banking came about in 1985 as part of the LTP, where it was also known inter-refinery averaging.

The LTP was “part of a regulatory program that mandated reductions in the amount of lead added to gasoline” (Hahn Hester 1989, p. 380). The banking of lead rights enabled producers who could not meet the new standards for additional lead within the specified timeframe, to trade with refineries that had been able to conform. While the features of offsets, bubbles, netting and banking contributed to cost savings for the emitting firms, they also added to the complexity of administering the process.

Pezzey (2003) proposed that a threshold level for a carbon tax could be used in a hybrid scheme. Others have also acknowledged this proposition in the literature. Proponents of a hybrid model have, in the past, included McKibbin and Wilcoxen (1997), Bernard, Vielle and Viguier (cited in Haurie and Viguier 2005), and Saeverud and Wettestad (2006).

The proposal that tradable permit programs are cost-effective in reducing emissions underpins the study, as it examines the use of market-based instruments for environmental regulation. The focus is on is what is known as cap and trade greenhouse gas emissions trading. In 2007, Reinaud and Philibert identified a group of blueprints for greenhouse gas emission trading schemes, at different levels of refinement.

In this study, both conceptual positions are discussed tradable permits (also known as cap and trade) and a carbon tax, although examples carbon taxes are not examined to the depth that tradable permits are.

The principle of tradable rights to the environment has been used before in transferable quota programs. A controversial aspect is the allocation of the right to pollute that did not exist previously. The allocation of this right is one of the barriers for greenhouse gas emissions trading in terms of community acceptance.

There are examples of environmental problems that have been addressed by transferable quota programs. Common and Stagl (2005) provide a comprehensive list of transferable quota schemes that operate in OECD countries. Described are schemes that have been used for regulating the salinity of rivers, distributing hunting rights, and the issuance of rights to develop forest areas. Considerable use has been made of tradable quotas to manage air borne pollutants. Globally, the use of individual transferrable quotas (ITQ) to manage commercial fishing stocks is considered a standard approach (Stavins 2011).

The ITQ system exhibits flexibility as the number of quotas issued for an individual species can be adjusted to align with the variation in fish stocks. The extensive use of ITQ for commercial fishing rights has been studied in Australia, Canada, Iceland, New Zealand, and the US. A potentially negative aspect (for some fisherman) of these programs is that the smaller participants, in terms of catch size, have been forced out of the market by larger fishing operators. On the positive side, it is considered that the use of ITQ may have improved the safety of fishing crews that do not have to endure extended periods at sea due to reduced seasons as quotas are filled.

This study examines the data that is available from prior tradable permit programs. It also examines the data that is available from existing programs for greenhouse gas emissions trading. It aims to look at the factors that are fundamental to the implementation and operation of greenhouse gas emissions trading. It was anticipated that examination of the compliance data for the participants in existing programs would also reveal how successful the process has been in the reducing greenhouse gas emissions.

The ability of greenhouse gas emissions trading to achieve large scale emissions reduction has now been acknowledged. The US EPA has been collaborating with the Chinese State Environmental Protection Administration (SEPA) to bring a large-scale trial of emission trading into being. The US Acid Rain Program has been used as a model for China to improve air quality by removing the sulphur from the emissions of a variety of heat sources (Wang et al. 2011). Under environmental pressure to reduce emissions of SO_2, this collaboration has produced a workable policy for the implementation of emissions trading.

In respect of greenhouse emissions trading, the EU ETS and the RGGI have become became a proving ground for these flexible mechanisms. Subsequently, and without the existence of a federal program, several regions within the US now participate in cap and trade emissions trading.

The literature also reveals the many policy difficulties accompany the implementation of a large-scale emissions trading, particularly when regional differences are significant. In the European community, the taxing of polluters has been widely used to reduce damaging environmental effects. In contrast, in the US there have been experiments with a market-driven trade in permits for the right to pollute. The participation of the US and China, as large suppliers, and buyers of emission credits, is still required for the international effectiveness of the Kyoto mechanisms.

Each country has a different set of responses to their main sources of greenhouse gases, such as CO_2. The stationary energy sector, mining and industrial processes, transport, agriculture, and waste management have variously emerged as leading contributors in several models. The pressing concern for governments is the design of ETSs that minimise the impact of abatement on welfare (e.g., employment, GDP, and the terms of international trade). So, the proponents of Kyoto's flexible mechanisms suggest that developing a domestic market in the trade of emission permits, which can be linked to international markets, is the most cost-effective way forward.

It was envisaged that flexibility mechanisms could guide industrialised countries toward establishing a domestic tradable market for emission permits. Sonneborn (2005) identified the onerous task of developing the required new capacities to support the regulatory and administrative processes of a market-based approach to the mitigation of greenhouse gases.

2.4 The development of greenhouse gas emissions trading

Over time light has been shed about the design of programs for greenhouse gas emissions trading in the wider context of environmental regulation (Nolles 2007). As early as 2007 the World Bank considered that enough experience of this process had been established to provide data on the performance of several programs. Research conducted by government and non-government bodies to illuminate the potential greenhouse gas mitigation strategies was also a source of data for this study.

These bodies include the UN WGs of the IPCC (e.g., WG III (Metz 2007)), the US EPA (USEPA 2010), the European Commission, the UK Treasury (Stern 2006), the Australian Government (Garnaut 2008), the Pew Centre on Global Climate Change (Strachan 2005), Resources for the Future, Washington (Palmer et al. 2009), and the MIT Centre for Energy and Environmental Policy Research (CEEPR) (Ellerman et al. 2009).

With a number of examples available to research, the international communities continued promotion of emissions trading (Flachsland 2008). Enquiry is warranted to determine what evidence can be gained from the two main case studies in this study.

Adding to the knowledge about the use of market-based mechanisms for environmental regulation.

The approach in this research has been to draw out of the literature some key constraints to emissions trading and some of the fundamental factors that should be considered when designing a scheme for GHG emissions trading. The constraints are associated with acceptance, effective operation and emissions reduction.

Light is thrown upon the factors influencing both the acceptance of an ETS as a national or regional institution and the effectiveness of such a trading scheme in reducing emissions. One issue of interest is whether the factors that facilitate acceptance of an ETS tend to be inversely correlated with those necessary to ensure that the scheme reduces emissions.

The literature on the regulation of the environment indicates that because markets do not work perfectly, government intervention in environmental issues is required (Ash 2012). Such measures are known as command and control (CAC) and, according to Lejano and Hirose (2007) and Tietenberg (2006), have been used in the past as a more familiar method for addressing pollution. The move toward applying a monetary value to pollution was developed under the Pigovian taxation regime (Baumol & Oates 1988), with pollution (an undesirable externality) taxed at the source. An ETS is a quantity-based approach to account for such an undesirable externality. A carbon tax on the other hand is a price-based approach (Pearce 2003).

Proponents of a carbon tax often refer to the marginal abatement cost curve (MACC), which indicates that a tax can be cost-effective in the early stages of greenhouse gas abatement when abatement costs are relatively low (Nordhaus 1993, 1991; McKitrick 1999). The MACC graphically represents the cost of abatement plotted against the corresponding reduction of greenhouse gas emissions over time.

It has been acknowledged that the allocation of permits or the right to emit a tonne of CO_2 is a critical issue for the design of a greenhouse gas emissions trading scheme (Helm & Pearce, cited in Helm 1991; Janissen 2000; Burtraw et al. 2001; Harrison & Radov 2002; Burtraw, Palmer & Kahn 2005; Harrison et al. 2007).

The US ARP aimed to reduce emissions of SO_2 and was an important precursor to the later schemes for greenhouse gases. As with the later designs (Svendsen 1998, p. 126), the US ARP included an allocation of allowances based on the historical level of emissions from a facility, known as grandfathering, or the free, initial distribution based on the average use of fuel sources.

The arguments against free allocation suggest that it could introduce barriers to entry for subsequent participants in an industry. Free allocation of allowances may provide a perverse incentive to individual firms in behaving less than efficiently, causing distortions in the market. Janissen (2000) also observed a missed opportunity to raise revenue from the potential auctioning of allowances.

It is widely held in the literature that the best outcome in terms of social welfare should be obtained when an auction is held to distribute a percentage of the total available allowances or emission permits. Following this, permits may be withdrawn from the market when an excess of permits and low permit prices become apparent. An alternative option, which is perhaps unlikely, could occur when additional permits are made available because a safety valve (high) price is reached, thus signalling an unsustainable scarcity.

The regulator of an ETS should determine a safety valve price (i.e., the point when more permits are released to the market) (Haites 2005). In the current relatively small segment of pilot schemes, the need for a safety valve price has not been warranted, as easily attainable emissions reductions targets have been set. Within the stationary energy sector, the free allocation of permits has the least impact on prices to the consumer, although it is suggested that the free allocation of allowances may be difficult to administer outside the energy sector (Burtraw et al. 2001).

Another option for the allocation of allowances is the ‘update’ alternative, with subsequent auctioning of allocations following an initial grandfathering of allocations. Harrison and Radov (2002) have identified several criteria for evaluating the cost-effectiveness of alternative allocation approaches. The best allocation methods will minimise additional costs to the participants.

Implementation and regulation of emission trading can be done without excessive through costs. An effective allocation strategy will also lower the potential for distortions of a trading market, such as unequal burden sharing of a narrow band of sectors in the economy. It has been stated that the primary difference between free allocation of permits and auctioning is the transfer of wealth to emitters under free allocation and to the government under auctioning (Kosobud et al. 2002).

In the past, there are a series of different processes for the allocation of permits in a program for emissions reductions. Examples of these include the US ARP for emissions of SO_2 where there was grandfathering combined with later auctioning of allowances. In the California Regional Clean Air Incentives Market (RECLAIM) (for SO_2 and oxides of nitrogen NOX), there was grandfathering used. In Denmark, for emissions of CO_2, the primary method of allowance allocation was grandfathering with some limited auctioning. The UK ETS and the Norwegian ETS, both for CO_2 were using a combination of grandfathering and auctioning.

Zerlauth and Schubert (1999) have examined the Californian RECLAIM program in the Las Angles area, which used a form of modified grandfathering. In the RECLAIM program, historical fossil fuel usage rates were used to calculate an appropriate cap to formulate the allocation of a RECLAIM Trading Credit (RTC). It was noted in this scheme that a provision for new entrants was necessary, using credits from a pool that was ‘ring fenced’ from the total available credits, or credits could be made available by the regulator buying back a block of credits with revenue raised from the program or special tax.

Part of the 1998 Kyoto Protocol, developed under the auspices of the UNFCCC, promoted a consensus between the collective of Annex 1 parties. This consensus was to be absolute in relation to the attainment of “quantified emission limitations and reduction commitments under Article 3” (UNFCCC 1998a, p. 1). The Protocol was not so prescriptive on the development of individual programs and suggested that the parties “formulate, where relevant to the extent possible, cost-effective national and, where appropriate, regional programmes to improve the quality of local emission factors” (UNFCCC 1998a, p. 9).

The EU ETS embraced the UNFCCC Kyoto protocol guidelines as well as the principles of JI and the CDM. These flexible mechanisms support the development, in parallel with the primary market, of a secondary market in equivalent allowances. There was the potential for intergovernmental trade in these secondary markets under the JI and CDM frameworks.

While the flexible mechanisms of JI and CDM were meant to support the development of complementary markets for allowances, the Kyoto protocol foreshadowed difficulties in any complementary trade under the JI and CDM frameworks. In this regard, parties were encouraged to "take steps to share their experience and exchange information on such policies and measures, including ways of improving their comparability, transparency and effectiveness" (UNFCCC 1998a, p. 2).

The UK ETS started in 1999 and ceased in 2007 as participants moved to the EU ETS. This scheme was initiated following recommendations in the 2008 Marshall Report, which suggested the UK ETS as a 'dry run' for interested parties. It also recommended an energy tax or user pays process for small to medium size enterprises. The business led advocacy in the building of the UK ETS resulted in a downstream orientation in which the user pays. The upstream orientation of the EU ETS meant that it was focussed toward the stationary energy sector and highly energy-intensive industries (Nye & Owens 2008; Von Malmborg & Strachan 2005).

Another greenhouse gas emission trading program was developing in Norway while the EU ETS was being contemplated. The Norwegian action on climate change began with the adoption in 1989 of a domestic greenhouse gas target, followed by the introduction of a carbon tax in 1991. The development by Norway of a domestic ETS was thought of an alignment of a sovereign position with the EU in terms of rule-based adjustment, interest-based adjustment, and ideas and learning.

The ETS proposed in Norway had ties to the plans for the EU ETS, as follows:

> (1) the proposed start up and timeframe for emissions trading, i.e., whether the policy was to introduce an ETS in 2008 (when the first period of the Kyoto Protocol starts) or start earlier; (2) the scope of the scheme in terms of greenhouse gases and sectors; (3) the method of allocation, i.e., grandfathering or auctioning;

> and (4) the non-compliance mechanism including the potential penalty fee. (Saeverud and Wettestad 2006, p. 94)

In response to a green paper released by the EC (European Commission Green Paper 2000), several important factors were identified in the design of a greenhouse gas market for the EU. The four salient issues were the "target group, allocation of emission allowances, how to mix emission trading with other instruments and the critical issue of enforcement" (Svendsen & Vesterdal 2003, p. 1532).

In terms of the target group, concerns have been raised about the abuse of market power in a concentrated market in which a small number of participants could hold many allowances and could skew the supply of allowances to the market. These distortions reduce the relative cost of their greenhouse gas abatement, while increasing the abatement costs for other participants in the trading market. Cason et al. (2003) believed that in such a thin market, the degree of dominance to achieve this would have to be great, perhaps as high as 90%.

2.5 The key elements of emissions trading

As the literature on tradable permits and on greenhouse gas emissions trading grows, the European Environment Agency (EEA) has provided the following definition for tradable permits:

> Tradable emissions permits are used in an environmental regulatory scheme where the sources of the pollutant to be regulated (most often an air pollutant) are given permits to release a specified number of tons of the pollutant. The government issues only a limited number of permits consistent with the desired level of emissions. The owners of the permits may keep them and release the pollutants or reduce their emissions and sell the permits. The fact that the permits have value as an item to be sold gives the owner an incentive to reduce their emissions. (EEA 2016)

The existing programs provide an opportunity to move the process of greenhouse gas emissions trading a little further, from unknown territory toward more familiar ground. Goulder (2013) suggested that the outcomes of cap and trade emissions trading can also now be better understood in relation to other related processes, such as complementary abatement policies and environmental taxation. A discussion on the results of the study and the influence the US ARP has had can now contribute to a conversation about tradable permit programs for greenhouse gas emissions trading.

In the case of the greenhouse gases, the price of allowances should reflect the marginal cost of the abatement options that are available at the time. Over time, depending on the alternative technologies that become available, the marginal cost of abatement is expected to rise due to permit scarcity. Typically, these abatement options have related to energy efficiencies, fuel switching, plant closures and subsidies for renewable sources of energy. In the literature, the cost of abatement is described by the MACC.

An option when allocating permits or allowances is to base the allocation on historical levels of emissions from a facility, as was the case in the US ARP and subsequent programs, where the initial allowances were allocated free of charge. This methodology can lead to an oversupply of allowances as emerged recently in the CCTP. Using emissions trading, the price of the allowances could also be set at an auction, as was the case in the RGGI.

Two of the earliest schemes to develop were the NGGAS in Australia and the UK ETS. The UK ETS would, it was thought at the time, provide exposure for businesses that were likely to be impacted by a carbon price. To take advantage of burden sharing, the UK ETS was quickly absorbed into the larger EU ETS. While in Australia, the NGGAS was replaced by the Australian carbon tax legislation of 2012 and has since lapsed following the repeal of the carbon tax in 2014.

Between 2003 and 2012, the Independent Pricing and Regulatory Tribunal of New South Wales (IPART NSW) had oversight of the NGGAS. Over this time IPART reported that the NGGAS was responsible for the creation of 144 million New South Wales Greenhouse Gas Abatement Certificates (NGACs). One NGAC represented a reduction of one tonne of carbon dioxide or equivalent (CO_2e). The operators of two coal fired power stations at the time, Liddell (plan to close in 2022) in New South Wales and Hazelwood (closed in 2017) in Victoria, reported that within the parameters of the NGGAS these two large stationary energy sources created a combined total of 7.1 million NGACs (IPART 2013).

Both NGGAS and the UK ETS provided some data about the behaviour of, in the case of NGGAS, upstream sources and, in the case of the UK ETS, downstream consumers. The NGGAS program was a variation of cap and trade emissions trading called baseline and credit. In a baseline and credit program, allowances are required only for emissions above a pre-determined baseline amount. While both programs have been superseded, the study has used data from them to assess the case studies.

Ellerman (2003) suggested there are several classes of tradable permits to be considered (i.e., credit trading, averaging and allowance trading). For credit trading, firms must meet abatement requirements that are at the baseline level as determined by a regulator. Credits can be obtained when the abatement levels are met and exceeded. In terms of emissions reductions, averaging occurs when the emission rate is set at pre-determined levels and then the emissions of higher emitting entities can be averaged with those of lower emitting entities.

The average emissions of all entities must reach the baseline level of emissions. It has been suggested that the credit and average types of tradable permits are only slight variations away from the more familiar CAC measures. The third type of tradable permits involves allowance trading, which is also known as cap and trade. Allowance trading requires that the emitting entities surrender an allowance for every unit of discharge. Ellerman (2003) identified the requirements for effective systems as, measuring emissions, allocating emission rights, and defining the pollutant.

The experience with the implementation of the processes for emissions trading has improved confidence about the economic efficiencies. This study has also identified several the flexible design decisions that are fundamental to efficient policy for GHG emissions trading. It has introduced some factors that are growing in importance when implementing programs for GHG emissions trading. These include the treatment of allowances as a financial asset, the compensation (exit and entry) provisions for new entrants, retiring plant, and the importance of managing excess allowances.

In addition to the UK ETS and the NGGAS, there are several other operational allowance programs for other air borne pollutants, mainly in the US. Here, the pollutants that were targeted were NO_x and SO_2, but it has been suggested in the literature that there were conditions in the NO_x and SO_2 program markets that also would hold for CO_2 as the principal GHG (Burtraw et al. 2005). This study is placed within the literature at this point as it focused on what worked in terms of policy decisions in relation to the operation of the US ARP.

A series of salient issues have been raised in the programs for tradable permits. Schneider and Wagner (2003), in an assessment of the applicability of using data from prior programs, identified what they described as ten key design issues. These were: trading of emissions versus inputs; mandatory versus voluntary; absolute versus relative baselines; grandfathering versus auction; allocation and efficiency in the international context; banking and borrowing; market power and the design of emission permit markets; market efficiency, transaction costs; enforcement and management framework; and the interaction between international and domestic policies (Schneider and Wagner 2003).

While the UNFCCC has guided the discussion about the potential of using market-based instruments, several institutions have developed the argument further. Resources for the future based in Washington DC sponsored a book by Thomas Tietenberg called *Emissions Trading, an Exercise in Reforming Pollution Policy* (1985). Tietenberg debated the designs for tradable permit programs that emerged in the wake of the CAA of 1990 (US EPA 2000), including the US ARP.

In his book, Tietenberg viewed emissions trading considering a perceived cost-effectiveness and distributional flexibility, alongside important spatial (location) and temporal (time) considerations. The conceptual framework developed by Tietenberg also included aspects of market power and participant compliance. The draw cards for greenhouse gas emissions trading that were taken from the analysis by Tietenberg are cost-effectiveness, distributional flexibility, and international trade. These are discussed briefly below.

2.5.1 Cost-effectiveness

The perceived cost-effectiveness of emissions trading as opposed to the more familiar CAC regulation was (in terms of SO_2) achieved from the less rigorous requirements for establishing the value of permits. Cost-effectiveness was an attractive quality, although Tietenberg did acknowledge that there is a raft of factors that need attention because, as he put it, “any change in policy has its own set of costs, it is difficult to overcome the inertia of the status quo” (Tietenberg 1985, p. 38).

It was considered that the cost-effectiveness of emissions trading would be a strong determinant towards its potential application in the regulation of the environment. If the price of carbon allowances was taken as a metric, then the EU ETS and the RGGI could, arguably, be said to exhibit low cost operation. If the reduction of the anthropogenic greenhouse emissions was taken as a metric, then the outcome could be skewed against the market-based solution. This study found that the cause of this skew were the compensating factors that were introduced to get acceptance of the programs. These factors were found to be inversely correlated with actual emissions reduction.

In the case of the EU ETS, with a broad sectoral base, allowance prices were quite volatile in the first and second phases (see Chapter 4, Figure18). The RGGI on the other hand focussed on a single sector (i.e., power stations or stationary energy). Allowance prices in the RGGI at the completion of the first control period, despite some initial instability, remained low (see Chapter 5, Figure35). In the future, the distribution of abatement costs would, in theory, matter most when steeper emissions reduction pathways are introduced with binding targets and stringent compliance conditions.

Across the EU ETS and RGGI in the years that followed, these pilot programs and later in the CCTP allowance prices, at auction, have remained relatively low, perhaps a result of too many free allowances, easily attained targets and the gentle slope of the emission reductions trajectory. While there remains some free allocation in the EU ETS, auctioning has been progressively introduced and now the scope of the system has expanded to include aviation.

In the EU ETS, auctions between 2012 and 2016 resulted in an average allowance price of €5.90. The EU ETS allowance high price over the same period was €8.63 and the low price at auction was €2.63. (Europa 2016). In the RGGI, auctioning has been used to distribute allowances from the start. Auctioning between 2008 and 2016 has yielded an average allowance price of US$2.99. The RGGI allowance high price in this period was US$7.50 and allowance prices have been as low as US$1.86 (RGGI 2016). In the CCTP, although auctioning was the intended allocation method, there has been, in practice, a combination of free (direct) allocation and auctioning. Nevertheless, across the CCTP, between 2011 and 2016, there was an average allowance price of US$13.65, an allowance high price of US$23.75 and an allowance low price of US$11.55 (Climate Policy Initiative 2016).

A large amount of the greenhouse gas emissions covered are from the stationary energy sector, where stranded assets and plant closures have resulted in some windfall profits. It has been found that the allocation of allowances in this sector, either through direct allocation (free of charge), regular auctions or by both methods, as in the CCTP and EU ETS, is critical. The management of any excess allowances seems the key to perceived success or failure.

2.5.2 Distributional flexibility

Distributional flexibility stands out as being the element of cap and trade that could appeal to affected businesses, as it refers to the spreading out of the economic burden. Tietenberg considered that the greatest distribution of the economic burden could be achieved through emissions trading. It was proposed that distributing the burden of compliance would find the lowest control costs, as the affected firms were in the best position to identify the lowest cost actions. This in turn meant lower costs being passed on to the consumer.

Tietenberg also considered that the distributional flexibility that was inherent in broad based emissions trading would benefit consumers the most. Distributional flexibility refers to where the decisions to reduce emission are made. In the case of cap and trade emissions trading, the holders of allowances make these decisions based on where the most effective reductions can be made. In the case of the EU ETS, this distributional flexibility was exhibited in the secondary market for allowances that flourished. The burgeoning secondary market for allowances indicates that low cost options for emissions reduction had been found, which freed up allowances to trade.

Another less straightforward yet supposedly flexible component of emissions trading, according to Tietenberg, acknowledges that a third party that pays for control measures may not necessarily be the owner of the emitting entity. It is envisaged that the third party could reduce emissions relatively cheaply without making expensive changes to the plant. In this case, the third party providing cheaper emissions reductions could bank emission credits, which could be passed on to a secondary market.

At the time Tietenberg made these early observations, the looming climate change debate had not yet been raised. It was soon to be heralded by Grubb, who felt that by the late eighties the effects of global warming were justifiably concerning. Grubb went on to state that, “The political impetus for an international convention to address the problem is now considerable, but as yet there has been little analysis of the form which any agreement might take” (Grubb 1989, p. 2).

2.5.3 International trade

In 1990, Schneider discussed some of the international ramifications of the greenhouse phenomenon in a book titled *Global Warming: Are We Entering the Greenhouse Century?* Deliberations in 1992 at the Rio de Janeiro UN earth summit eventually led to the adoption of the Kyoto Protocol in Japan in 1997.

While greenhouse gas emissions trading came to be a response to global warming, there was an inherent problem. Policy design had not been able to resolve the conflict between developed and developing economies, in which a large disparity of greenhouse gas emissions exists. This disparity has fuelled resistance to international cooperation on both sides of the argument. At the time initial deliberations were taking place, the developed economies were responsible for about 80% of global anthropogenic greenhouse gas emissions (Patterson & Grubb 1992; Höhne & Blok 2005; Jotzo 2006).

The existence of prior environmental taxes would also add to the distortions introduced through international emissions trading, which could make the exchange of permits unattractive for some nations according to Babiker, Reilly and Viguier (2002). Jotzo and Pezzey (2007) argued that the use of tradable permits with fixed targets for emissions was likely to introduce uncertainty about the cost of compliance. This perceived risk to both developed and developing countries may have affected the recent concern on the future of any binding global agreements.

The EU ETS participant countries did develop burden sharing agreements, allowing countries that were more able to meet their commitments for reduction of emissions to assist other countries that could not. There are indications that international trade is an aim in emerging programs that favour cross border exchange of allowances. Australia, in its failed plans for emissions trading, was also looking further afield to the EU ETS. In 2013 the price of EU ETS allowances fell to AUS$3.34 a tonne and the threat of these allowances entering a future Australian market had raised concerns.

In examining these programs as models for their own designs, the Australian Government (2012) found that when considering greenhouse gas emissions trading there are other related areas to be focussed on. These include international linking and the governance of offsets. Linking refers to the potential trade in carbon allowances and offsets across program boundaries to take advantage of any abatement cost differentials. This cross border linking can potentially lead to a supply of allowances from a region where allowance prices are comparatively low.

It has been suggested that linking can be a direct form, when two regions interchange allowances on a like for like basis. Or, alternatively, linking can be an indirect form, when two programs accept some form of carbon offset. Zetterberg (2012) examined the policies of the EU ETS and the CCTP about direct and indirect linking and suggested that while transatlantic cooperation is not likely, there are some program similarities that warrant further investigation.

In parallel with the introduction of the EU ETS and the RGGI, there has been a range of activities occurring in response to the build-up of the anthropogenic GHGs. Some of these activities reduce emissions directly such as the wide uptake of renewable energy resources and the introduction of low vehicle emissions standards. In this study, while some alternative activities may fall under the description of alternative policy. They are considered as external to this study of the programs.

Other activities may have a less direct effect on emissions reduction, but they are changing attitudes in the built and the natural environments. The UNFCCC has also provided stewardship of the finance for developing countries to adapt to the impacts of climate change.

2.6 Examining designs for trading programs

This section reviews some examples of other ETS other than the main case studies themselves. As experience with emissions trading has grown in the US, several programs have emerged that utilise the theory of emissions trading to control air borne pollutants.

For example, the Los Angeles RECLAIM began in 1994, with the objective of setting a cap for the emission of SO_2 and NO_x, and it "created a market and industry that was not there – everyone had to learn how to do it" (Zerlauth & Schubert 1999, p. 280). However, there were unintended consequences that became apparent in the emissions trading scheme that resulted from RECLAIM. Firstly, there was an unmonitored trade in other gases, and an over allocation of allowances for NO_x, the RECLAIM program's most heavily traded pollutant. Also, the command and control measures, previously put in place to meet the requirements of environmental standards, were not fully utilised as the installation of control technology was delayed (Lejano & Hirose 2007).

Another cap and trade scheme, developed by the Illinois EPA for the management of air borne pollutants in the Chicago area, was called the Emissions Reduction Market System (ERMS). This appropriated the value of an Allotment Trading Unit (ATU), which entitled the owner to discharge 200 pounds of a "seasonal volatile organic compound" (Kosobud, Stokes & Tallarico 2002, p. 73).

In Europe, the UK ETS was a voluntary, learning by doing program, which was part of the UK's Climate Change Program (CCP), which also included an energy tax called the CCL. The CCL and the UK ETS were linked through CCA. Radov and Klevnas (2004) observed the importance of targets and trade in the UK ETS. They suggested that firms covered by the UK ETS had an incentive to achieve emissions reductions beyond their targets in order that the surplus could be sold or banked for later use.

Between 2002 and 2006, the participants in the UK ETS had a target for emission reductions of 3.8 $MtCO_2e$. Radov and Klevnas (2004) found that this would amount to

14% of their collective baseline of 27.8 $MtCO_2e$. There were also targets that applied for the period 2002-2005, with emission reductions of one-fifth of the overall (2006) target, resulting in targets of 0.79 and 1.51 $MtCO_2e$ for 2002 and 2003, respectively.

In terms of coverage, the literature refers to schemes having either an upstream orientation or downstream orientation. When there is an upstream focus, the program is aimed at the big emitters, particularly energy, fuel suppliers and heavy industry. The UK ETS, it is said, had a downstream orientation. The direct participants were large organisations and medium sized businesses. As a result, the sectoral coverage was inconsistent and resulted in a weak alignment with actual emissions reductions.

While the UK ETS had a long planning phase, it had a limited life span due to the impending EU ETS. In the three years over which it operated, the rules for the verification of baselines were not well established. The rules of a program are strongly aligned to effective operation. In the UK ETS, the plans for a phased introduction combined with modest ambitions for emissions reduction targets support the conclusion that in this case a phased introduction was not aligned with emission reductions.

During 2006, participants in the UK ETS transitioned to the EU ETS. In framing this study, some of the earliest data was obtained from observations on the policy for the UK ETS. While the UK ETS does not directly provide case study material for the research, it does indirectly. This occurs because the UK ETS was merged into the EU ETS under the NAPs and subsequent EU burden sharing arrangements. As a pilot greenhouse gas ETS, the UK ETS gave participating businesses some early exposure to the processes of monitoring and verifying their carbon emissions.

The rules for the UK ETS were provided in the DEFRA document titled *Guidelines for the Measurement and Reporting of Emissions by Direct Participants in the UK ETS* (DEFRA 2003). These rules encompassed, among other things, baseline emissions, dispute resolution and reporting requirements. As well as the protocols related to CO_2 emissions, importation of heat and energy, renewable energy, and process emissions. The UK ETS was a pilot scheme, intended to test a new market. As such, some rules for the verification of emission baselines were not in place at the start of the UK ETS (Radov & Klevnas 2004).

The initial allocation of allowances was significant for the UK ETS but did not proceed quite as was intended. In the UK ETS, the initial allocation of allowances was done through auctioning, as opposed to free allocation. A high permit price (£53.37 per tonne CO_2-e) resulted from the auction of initial permits, which raised concern about cost-effectiveness (Smith & Swierzbinski 2007).

California joined the WCI in 2007 and by 2008 the WCI included four US states and three Canadian provinces. The intention of the WCI was to introduce regional cap and trade combined with a cross border greenhouse gas registry (Caron, Rausch & Winchester 2015). Of the original WCI participants, only two have since introduced cap and trade programs. These are Quebec and California which, at the time of writing, have agreed to link GHG cap and trade programs.

As identified earlier in the study, each program for emissions reductions faces regional issues that skew the practical application of trade. In California, the CCTP was no different. The EU ETS model of wide sectoral coverage was adopted in the CCTP to take advantage of the distributional flexibility of cap and trade. The CCTP also followed the EU ETS lead in relation to a phased introduction and it also utilised an established governance structure, i.e., the CARB.

The cost burden for emissions reductions in the CCTP were shared in an economy wide program across the stationary energy, industrial and transportation sectors. This advantage was overshadowed by the phenomena of carbon leakage, as California is a net importer of power. Leakage in the CCTP is described as resource shuffling and is typified by power retailers looking for out of state sources of power to reduce their allowance commitment within California.

As the CCTP has progressed, there has been legislative change that requires power importers to surrender allowances for imported electricity (Caron, Rausch & Winchester 2015). Another important element affected by carbon leakage or resource shuffling was the cap for annual emissions. The objective of the CCTP was to reduce emissions to 1990 levels by 2020. Resource shuffling has meant that, in a similar fashion to the EU ETS, the CCTP has seen the rise in the level of excess allowances. This means the annual cap becomes easier to achieve.

Complementary policy has played an important role in terms of how emissions reductions are accounted for in the CCTP. The California Air Resources Board (CARB) has overseen the implementation of renewable energy targets and energy efficiency standards (Cullenward 2014). It was identified that complementary policies within California would account for two-thirds of the required emissions reductions with one third covered by the CCTP (Wara 2015).

More than most prior systems, the CCTP appears, due to detailed governance, to have benefited from the designs for cap and trade that have preceded it. The operational document that describes the parameters of the CCTP is called the *Regulation for the Californian Cap on Greenhouse Gas Emissions and Market Based Compliance Mechanisms*. The comprehensive listing of definitions and rules contained in this document reflect the evolving nature of the guidelines for cap and trade.

Areas covered by the final regulation order of the CCTP were listed under several sub-articles: purpose and definition; applicability; compliance; registration; allowance budgets; covered entities; disposition of allowances; direct allocation (free distribution); auction; trading and banking; linkage; offset credits; enforcement and penalties. Detailed information was also included on auction dates and transparency of reporting (Office of Administrative Law 2016).

2.7 Carbon taxes

While scientific assessments continue to confirm the need for immediate action on climate change (US EPA 2010; Holland 2011; CSRIO 2012), historically carbon pricing either through taxation or trading has received a mixed reaction both in political and academic circles. The pricing concept is unpopular due to the cost of living increases and the impact on jobs. Stavins (2011) considers that the introduction of emissions trading is perceived as the introduction of a carbon tax and is not trusted, as it is a relatively unproven approach. Evidence for this is found in the scrapping, in Australia, of the legislation for a carbon pricing mechanism or carbon tax.

Turkey is an example of an economy in transition, with the government seeking to move away from CAC policies. Under the auspices of the Kyoto Protocol, Turkey favours the flexible mechanism of JI, offered under linkage arrangements in the EU ETS.

Telli et al. (2007), in their modelling of JI to meet emission targets, anticipated that foreign investment equal to 1.5% of GDP would be needed. In their opinion, the best available technology is a “CO_2 quota-cum-carbon tax” (Telli et al. 2007, p. 338) that would only apply to specific sectors. There would also need to be tax burden relaxation elsewhere in the economy to maintain levels of employment. Sectors modelled on the supply side of the Turkish economy were agriculture, coal mining, petrol and gas refining, electricity generation, cement, paper, iron and steel production and transportation.

In Belgium, Voorspools, Peersman and D’Haeseleer (2005) found that a selective CO_2 tax may be just as effective as emissions trading. A CO_2 tax was chosen because it lessened the uncertainty about a carbon price. As well, the sources of emissions are readily identifiable. There is no allocation of allowances required and the complicated central administration required for a tradable permit scheme is avoided.

Voorspools, Peersman and D’Haeseleer also identified several positive aspects in a tradable permit scheme, which were: the inclusion of flexible instruments, specificity in the meeting of targets, and that, in theory, a tradable permit scheme could facilitate linkages between the schemes in several countries.

In Switzerland, the Federal Office for Environment support a carbon levy that varies between sectors (FOEN, 2009). The Swiss greenhouse gas emissions profile is somewhat unique, as household heating is responsible for the most CO_2 gas emissions and the next largest contribution is from the transport sector. Emissions from the electricity sector are minimal due to large hydroelectric capacity. In modelling the Swiss economy to be Kyoto compliant, with its emission reduction target of 15%, it has been said that an increased carbon price certainty results from utilising the characteristics of the McKibbin and Wilcoxen (1997) hybrid tax and trading policy, discussed previously.

A correlation has been found between the carbon price in the EU ETS and the rate of reduction required to meet the levels in the Kyoto targets. It is estimated that at a reduction rate of 15%, the closing price for carbon could be US$313 or 117 Swiss francs. It is considered that a carbon tax rate would need to be levied at 210 Swiss francs to achieve the equivalent reduction rate of 15%. A price of 55 Swiss francs was considered the safety valve level, or trigger price, at which a carbon tax would apply in a hybrid policy of domestic trading and a carbon tax.

However, several governments agree that emissions trading may be the most cost-effective approach (Stavins 1989). Due to the perceived increased cost to welfare inherent in a carbon tax, it is argued that the Swiss economy would benefit slightly from joining the EU ETS, while also pursuing greenhouse gas emissions reduction through voluntary measures and the importation of emission rights through the flexible Kyoto mechanisms of CDM and JI (Bernard et al. 2005).

The Australian carbon tax was to be a precursor to a national greenhouse gas emissions trading program. Legislation included an annual fixed price period for three years (2012-2015), which would result in a price per tonne for CO_2-e of between AUS$23 and AUS$25. After a fixed price period, there was to be a period of flexible pricing, where "the price of emission units is not fixed but varies according to the balance between the supply of those units from within the ETS pollution cap, domestic offset projects and international carbon markets" (Australian Government 2013a, p. 3).

The legislation for the short-lived Australian carbon pricing mechanism, or carbon tax, went further than three previous proposals for greenhouse gas emissions trading in Australia. The Australian Greenhouse Office (AGO) first released its comprehensive discussion papers on greenhouse gas emissions trading in 1999. Building on the AGO platform, plans were developed by the National Emissions Trading Taskforce (NETT) in 2007 and the CPRS in 2008. None of these earlier designs made it past the legislative hurdle.

The primary objective of the Australian carbon pricing mechanism was to put a price on carbon, which, in turn, would potentially make heavy emitting activities less attractive from a business perspective. This mechanism formed the basis of the previous Australian Government's Clean Energy Future program. Critics of a carbon tax have stated that it does not ensure that an accurate value is placed on the externality of pollution.

2.8 Australia's position in 2010 in terms of global emissions

The following section briefly illustrates the historic position of Australia compared to other countries and their aggregate emissions of CO_2. At the beginning of the study the metric, *estimated percentage of global CO_2 emissions (estCO_2)*, was introduced for comparative purposes. The data for this comparison has been derived from the UNFCCC reports of several countries that are considered significant emitters. In relation to the data quality of countries reporting their greenhouse gas emissions according to IPCC guidelines, the UNFCCC suggested that:

> The quality of data is regularly checked through the UNFCCC review process for the Annex I Parties to the convention that report the data annually. Non-Annex I countries do not report the data annually and their data are not subject to the same review procedures. Data quality depends on the quality of statistics underlying the calculations or estimates and is usually the best for energy related emissions; because of differences in completeness and quality of the estimates, the data should be used with caution when comparing countries. (UNFCCC 2010)

During 2010, data collected by the UNFCCC suggested that a relatively small group of countries represented, on a global scale, a relatively high level of total CO_2 emissions. In 2010, these countries included the US, with 6924.56 million metric tonne (mmt) or an estimated 22.5% of global estCO_2. At the time, China recorded emissions of 4057.62 mmt (13.2%) and the Russian Federation 2229.5 mmt (7.2%).

Between 2010 and 2012, China became the dominant global emitter of greenhouse gas as their total emissions of CO_2 approached 8000 mmt (Jiang 2014). In 2012, it was reported that the six largest greenhouse gas emitters (by estimated percentage of globally emitted CO_2) were China (29%), the US (15%), the EU (11%), India (6%), the Russian Federation (5%) and Japan (4%) (Oliver et al. 2013). The rise in emissions from China accompanies, among other things, significant growth in the use of coal for energy production (Garnaut 2014).

Australia is considered a high per capita emitter of greenhouse gases for a UNFCCC Annexe 1 industrialised country, in the order of 24.3 tonnes annually (UNFCCC 2012; UN 2012).

The 2010 UNFCCC report positioned Australia in a group of countries that included Japan at 1281.82 mmt (estCO_2 4.2%), India at 1214.25 mmt (3.9%), Canada at 734.42 mmt (2.4%), Australia at 549.54 mmt (1.8%). Others were: Republic of South Korea at 542.89 mmt (1.8%), South Africa at 379.84 mmt (1.2%), Indonesia at 334.19 mmt (1.1%) and Saudi Arabia at 165.27 (0.5%).

Almost a decade later, in December 2019, the Australian National Greenhouse Gas Inventory identified per capita emissions that were in the order of 21 tonnes and in terms of national emissions the figure was 532.5 mt. This represents a reduction from 2010 to 2019 of 3.1%.

Given the required CO_2 emissions reduction sought by the UNFCCC and the preference for emissions trading, there are relatively few operational greenhouse gas ETSs. Some examples include the New Zealand ETS, EU ETS, US RGGI, US Western Climate Initiative, Californian CCTP, the South Korean ETS and several programs emerging in China.

2.9 Australian carbon pricing

While Australia remained outside of the 1997 Kyoto Protocol as an observer for ten years, it ratified the Protocol in 2007. The government of the day applied a controversial carbon tax in 2012 which was later repealed following a federal election. The incoming government introduced a direct-action plan and the Emissions Reduction Fund. The direct-action plan supports what are known as alternative policies (to emissions trading) in the form of a carbon offset market.

The literature review identified examples of prior research that indicates a convergence between the somewhat interchangeable approaches of environmental taxes and tradable permits (Grubb 1990; Stavins 1995; McKibbin et al. 1999). It has been suggested that because of this convergence there has been the development of hybrid designs. A hybrid design is distinguished by a fixed price component, a tax, combined with allowances for greenhouse gas emissions trading (McKibbin & Wilcoxen 1997; McKibbin et al. 1997).

The hybrid approach is also aligned to the use of a carbon price collar in the early stages of an ETS to contain potential allowance price excursions (CRPS 2008; McKibbin et al. 2009). This hybrid approach (McKitrick & Collinge 2000; McKibbin and Wilcoxen 2002) was proposed in the Australian carbon pricing mechanism, which started as a carbon tax that was in effect between 2012 and 2014.

The design of the CPRS merged existing international thought on emissions trading with specific research in an Australian context, to produce a national model (Garnaut 2008). In Australia, the CPRS was developed as a comprehensive market-based response to climate change. The CPRS white paper was released in December 2008 and the CPRS Bill was defeated by a margin of 41 to 33 votes in December 2009. The CPRS aimed for wide economic coverage to distribute the burden of compliance, although the inclusion of agriculture was to be delayed due to uncertainties with the greenhouse gas accounting measures.

Research was carried out in the context of the changing Australian approach to greenhouse gases emissions, as discussed by Sandu (2007), Howe (2007), and Sandu and Sharma (2010). To gain acceptance, it has been common in the pilot programs for greenhouse emissions trading to set modest reduction targets at the start. Some critics of emissions trading hold the view that the targets for emission reductions are inadequate for the desired environmental outcomes (Walters & Baird 2009). Regarding emissions trading programs, generally there has been concern about the polluters being given the right to pollute at a price determined in an unproven marketplace (Pearce 2003; Beder 2009; Pearse 2010).

A phenomenon known as carbon leakage was also a concern. This occurs when a business moves offshore due to economic considerations, such as increases in the costs of production or trends in a market, such as declining demand. In planning for the CPRS, it was recognised that there were scenarios that could lead to a weakened trading position for some, so called, trade exposed emissions intensive industries (TEEII). As a result, policy in the CPRS Bill defined a band of products that would be eligible for compensation.

There was also to be compensation for eligible households in the CPRS, as well as a ‘cent for cent’ reduction on fuel tax (Australian Department of Climate Change 2008). Costs in relation to transport and energy were expected to rise (Tulloh 2009). There was also a risk of job losses in the stationary energy and coal mining sectors (Adams 2007). The CPRS Bill coincided with the GFC and a steady rise in the price of gas, water and electricity, relative to the Australian consumer price index (CPI) (Plumb & Davis 2010). Organised labour groups were concerned about the implications for employment following the introduction of a CPRS (AWU 2009).

In a broader sense, it has been noted regarding major policy reforms such as the CPRS that:

> …no single policy instrument, whether market-based or conventional, will be appropriate for all environmental problems. Which instrument is best in any given situation depends on the characteristics of the specific environmental problem and, the social, political, and economic context in which the instrument is to be implemented? (Stavins 2005, p. 56)

In 2012, the incumbent Australian government implemented a controversial carbon tax. While the carbon tax legislation was new, the governance for a carbon constrained future had been in existence for quite some time. The clean energy future for Australian policy on pricing carbon was governed by a diverse group. The Climate Change Authority that oversaw the carbon tax would also have been responsible for the targeted level of emission reductions in any subsequent cap and trade scheme.

A group of activities were fundamental to the clean energy future, such as the National Greenhouse Energy Reporting (NGER) scheme and Renewable Energy Target (RET) scheme, and the Australian National Registry of Emission Units (ANREU) and Carbon Farming Initiative (CFI). Several government departments also advised on matters related to local and overseas industry (the Productivity Commission) and opportunities in agriculture (the land sector and Biodiversity Advisory Board). The Energy Security

Council assessed network security and assistance to fossil-fuelled electricity providers (Australian Parliament 2011).

In the wake of a change in government from 2014, a new department of environment and climate change was introduced to oversee climate policy in Australia. This department developed a further policy platform for Australia, i.e., the Emissions Reduction Fund (ERF). The ERF is directed at downstream emissions under confidential contractual arrangements. The expectation is that emissions can be mitigated from energy efficiency measures or land use changes.

A primary market for Australian carbon credit units (ACCUs) develops through auctioning and a secondary market is likely to emerge following the initial distribution. Observation of the ERF confirms the view that it introduces, through government subsidy, a shadow carbon price that could be useful as an internal budgetary tool for businesses exposed to future emission abatement. In Australia, hybrid arrangements such as the ERF are received more favourably than either environmental taxes or tradable permits. Alternatives such as hybrid schemes promote trade-offs to be made in terms of overall efficiency and limit the potential emissions abatement. These trade-offs affect the cost-effectiveness, the steepness of the pathway for emission reductions and overall sectoral coverage.

A primary market for ACCUs developed through auctioning in April 2015, when the average price per tonne of abatement was AUS$13:95. The downstream focus of the ERF, i.e., away from the sources of greenhouse gas emissions, is similar to a prior emissions trading program, the United Kingdom (UK) voluntary greenhouse gas ETS, circa 2001.

At the end of 2014, total Australian greenhouse gas emissions were 542.4 million metric tonnes (mmt). It was reported that in the 2014/15 financial year Australian total emissions had risen, by 1.3%, for the first time since the 2006/07 financial year (Australian Government 2015). In March 2020, the National Greenhouse Gas Inventory listed Australian emissions at 528.7 mmt, down 1.4% from the previous year. Indicating that between 2014 and 2020 greenhouse gas emissions in Australia have fallen 2.6%.

After the double dissolution federal election held in Australia during July of 2016, the incumbent government, under new leadership, was returned with a one-seat majority. The independent government advisory body on climate change, the Climate Change Authority was retained following this election and it continued to support market based environmental management as the most cost-effective way to mitigate greenhouse gas.

It was not a surprise when a carbon pricing mechanism was not a part of the Australian INDC submitted to the UNFCCC in 2015, the Australian INDC proposes a reduction in greenhouse gas emissions of 25-28% on 2005 levels by 2030 (Australian Government 2015).

It has been difficult in Australia to pass any carbon pricing legislation, as evidenced by the programs that are shown in Table 1, below. Since the AGO first contemplated a national ETS in 1999, political will has shifted and the plans for an ETS were mothballed. After Australia ratified the Kyoto protocol in 2007 a proposal for emissions trading was put forward, the CPRS, in the Garnaut Review of 2008.

Australian state governments have since set their own ambitious emissions reduction goals. South Australia is seeking to achieve 100% renewables by 2030 and the ACT has also set a 100% renewable target (Mazengarb 2020). The Victorian VRET 2 aims for 50% renewables by 2030 (DELWP 2019). New South Wales is hoping to reach net zero emissions by 2050 (ENERGY NSW 2020). The NSW plan reduces emissions from electricity generation in dedicated renewable energy zones that are based on wind, solar and battery storage.

Table 1: Australian carbon pricing mechanisms

Date	Carbon pricing governance mechanisms, proposed* and actual
1. 1999	Emissions trading scheme (Australian Greenhouse Office) *
2. 2001	Renewable energy target
3. 2004	National Emissions Trading Task Force*
4. 2007	National Greenhouse Gas and Energy Reporting Act
5. 2008	Carbon Pollution Reduction Scheme (cap and trade) *
6. 2011	Carbon Farming Initiative
7. 2012	Carbon Pricing Mechanism (carbon tax)
8. 2014	Emissions Reduction Fund (downstream focus)
9. 2016	Emissions intensity scheme (a variation on baseline and credit) *
10. 2017	National Energy Guarantee (baseline with a downstream focus) *

As this study concluded, the main policy platforms for Australia are the long standing RET and the ERF. The ERF is directed at downstream emissions under confidential contractual arrangements. The expectation is that emissions will be mitigated from energy efficiency measures or land use changes. Both individual and aggregated projects are allowed. A limited market for the ACCUs has developed in the wake of ongoing auctions and a secondary market may emerge to redistribute the ACCUs.

The Climate Change Authority expects that an enhanced suite of policies, that includes the ERF and the RET, will be required to achieve the targets for emission reductions that were put forward at the UNFCCC COP in Paris during 2015. A the time the Authority favoured the introduction of a market-based carbon pricing mechanism applied across the stationary energy (electricity) sector (Climate Change Authority 2016).

The Climate Change Authority has indicated support for one of two forms of a market-based mechanism, either cap or trade or the newly designed emissions intensity program. In its deliberations, the Australian Climate Change Authority revisited modelling from Frontier Economics (2009) which is supplemented by the more recent modelling of the Jacobs Group (2016).

Out of this modelling, economic indicators point toward the use of a market-based approach in the form of, in the first-place cap and trade and secondly a variation on baseline and credit known as an emissions intensity scheme (EIS). It is generally held that under a baseline and credit approach an upper limit for emissions is set and permits are required for any emissions above that baseline (McLennan Magasanik Associates 2009).

In 2017, a variation on the baseline approach was proposed by the incumbent government at the Council of Australian Governments (COAG) meeting in Adelaide. The proposal became known as the National Energy Guarantee (NEG) and was developed by the Energy Security Board (ESB) who referred to the policy as an emissions guarantee (Schott et al. 2017).

The ESB believed, as the NEG provided no compensation and did not require allowances to be issued, it was not a carbon pricing mechanism. A hybrid scheme such as the NEG can provide a shadow carbon price hidden in the contractual arrangements between electricity retailers and generators. Under the NEG emissions intensive export exposed industry would be exempt from emissions obligations; these obligations were to be met by other participants in the National Electricity Market (NEM).

The ESB had indicated that in Australia a rapid uptake of relatively unstable renewable energy in the NEM exposes the network to a lack of the spinning generation reserve that was historically provided by the more stable base load power stations. The NEG was an ambitious policy that sought to provide electricity supply security, reduce greenhouse gas emissions in line with international obligations while keeping electricity prices low.

The NEG is said to have downstream focus in that would require the states to ensure security requirements were being met by the retailers. Retailers would be required to enter contracts for power of an acceptable emissions mix from generators in the NEM. This contrasts with the upstream focus, on the sources of the greenhouse gas emissions, that is a feature in many designs for cap and trade – the NEG was shelved by the government prior to the 2019 Australian federal election.

Reporting greenhouse gas emissions in Australia

The Australian greenhouse gas accounting measures are not a subject of this comparative study. The greenhouse gas reporting database established in Australia does provide an example of how the reporting process can be handled. In Australia, there has been legislation for the reporting of greenhouse gas emissions since 2008. This reporting requirement emanated from the National Greenhouse and Energy Reporting (NGER) Act of 2007. The Australian Government later appointed an independent statutory authority known as the clean energy regulator. The regulator established a climate change portfolio that encompassed the Carbon Farming Initiative, the Carbon Pricing Mechanism (repealed in 2015) and the Renewable Energy Target.

At the time of writing, the NGER was jointly overseen by the Department of the Environment and Energy and the Clean Energy Regulator. In 2018, the Climate Change Authority, as an independent statutory agency released a report into the NGER and its Safeguard Mechanism. The report indicated that in 2016-2017, 63% of Australia's GHG emissions were reported to the NGER.

The Safeguard Mechanism commenced in 2016, in the words of the Climate Change Authority it:

> …aims to ensure emissions reductions purchased under the Emissions Reduction Fund are not offset by significant increases in emissions above business-as-usual levels elsewhere in the economy. (Climate Change Authority 2018, p. 22)

2.10 Limitations of the literature review

The literature review has been focussed on the practical application of greenhouse gas emissions trading and design factors associated with its implementation. This focus has limited the examination of some key aspects of tradable permit programs. These aspects are related to industry sectors covered by a program and the implications of cross border and international trade in allowances.

Sectoral coverage

Sectoral coverage varies considerably between the existing designs for emissions trading. This is exemplified in Australia, where fossil fuel use and per capita emissions are high and the choices in sectoral coverage are not influenced by ecological concern as much as by economic and political viability. Garnaut (2008, p. 328) suggested that, in the Australian context, "Stationary energy, industrial processes, fugitives and transport should be covered from the outset. Waste and forestry should be covered as soon as practicable. The inclusion of agriculture should be subject to progress on measurement, administration and cost effectiveness".

In the RGGI, participants are limited to stationary energy sources above a capacity threshold. The EU ETS applies to stationary energy and coverage has grown to include up to 11 other industrial sectors and European aviation (Europa 2008; EC 2020). In the modelling for the Kyoto Protocol regarding emissions trading and capital flows, up to twelve industrial sectors have been used (McKibbin et al.1999).

Since the 1950s, the build-up of greenhouse gas from land use management and land use change (fertilisation, water management, manure management, and forest rotation length) accounts for one-third of total anthropogenic CH_4, N_2O, and CO_2 emissions (Houghton 2003 cited in Fisher 2007). Deforestation contributes up to 20% of anthropogenic emissions worldwide, and transportation is the fastest growing contributor to CO_2 emissions globally (Clemencon 2008).

The EC suggests that since 1990, EU emissions from aviation have almost doubled. Aviation was included in the EU ETS with proposals for 85% of allowances to be issued free and 15% to be auctioned (Runge & Metzger 2011).

International trade

A long held goal of the parties to the UNFCCC has been global trade in allowances under the flexible Kyoto mechanisms. Sprinz and Luterbacher (1996) have observed that, since the early 1990s, the literature about the establishment of international linkages to allow cross border trade in emission allowances has been growing. Others support the view that the body of literature on the possibilities of coordinated international action has been growing steadily (Garnaut 2008a; NETT 2007; Shergold 2007).

An obstacle to discussions on international action is what Paterson and Grubb (1992) describe as the north-south divide. They allude to the large emission related inequities between developed and developing regions. Helm (1991) suggested that, in theory, the attraction of international emissions trading is its straightforward framework. Tietenberg et al. (1998), Flachsland et al. (2008) and Ellerman (2008) have stressed the potential for learning in the international community from prior programs for allowance transfers. These authors also identify the EU ETS as a model for a bigger (international) trading regime.

Yamin (2005, p. 26) suggested that international trade requires the capacities of “binding targets, robust reporting, and a strong national and international infrastructure”. Some benchmark capacities to comply with the emission trading boundaries are described in articles agreed to in the UNFCCC Marrakech Accord of 2001. The relevant modalities were stated by Den Elzen and de Morr (2002, p. 142) as “international emission trading, (IET), joint implementation (JI), and the clean development mechanism (CDM); land use; land use change and forestry; compliance; monitoring and reporting and financing for developing countries".

Summary

The period covered in the literature review considers the evidence from several sources that indicates, after acrimonious debate, there are global markers that indicate a warming planet and the urgent need for action. While the concept of a tradable environmental permit remains controversial, the main theme represented in the literature review has been the idea that a market-based approach can be useful in the mitigation of greenhouse gases.

While the literature review has shown how the UNFCCC has guided the ongoing discussion about the science behind global warming and the required level of global mitigation of the greenhouse gases. The literature review also finds that decisions about relative merits of the mechanisms to achieve the required level of mitigation may need to be made at a national level.

The role of human adaptation has grown in prominence over the period of the study, as has a pessimistic outlook toward limiting the average global temperature increase (European Commission 2016a). The UNFCCC has provided a nexus for potential global action, although international cooperation remains difficult to achieve.

The literature review covers the comparative policy approach taken by several prior researchers (Aldy et al. 2003; Ellerman et al. 2003; Hansjurgens 2011; Chan et al. 2012; Schamalensee and Stavins 2013 & 2015) and more recently Narassimhan et al. (2018) and Haites et al. (2018).

Elements of this study that differ from earlier research are its longitudinal nature, the introduction of three key constraints and the framework of nine factors that have been drawn from the tradable permit literature. Detail about the strategies for collecting and manipulating the data from the case studies is expanded in Chapter 3.

Chapter 3: Methodology

3.1 Introduction to the methodology

The study takes a prospective approach to develop a comparative study to assess the success, or not, of recent tradable permit designs. Secondary data is collected on several earlier tradable permit programs. The study identifies design factors found to be common across these various schemes. The data on the design factors of emissions trading is triangulated using the three data sources shown below in Figure 2: Triangulation of data sources.

In Section 3.2, Table 2 summarises examples of the prior related comparative research. Including research on the impact that the GFC and at the time of writing the COVID-19 pandemic can have on emissions. In Section 3.3.1, Tables 3-11 consider the relevance of the nine design factors to a program for greenhouse gases (UK ETS) and SO_2 emissions trading (US ARP).

Section 3.4 develops the criteria for the weighting of the design factors. Tables 12-17 contain the factor weightings for the main case studies. These weightings form the basis of the entries in Table18: Factor strength of alignment with the constraints.

The first source of data was the tradable permit literature, which was used to elaborate on the factors that are fundamental to the design and implementation of tradable permit programs. The next source of evidence was prior quota programs that have dealt with a range of airborne pollutants including SO_2. The third source of data are a small number of pilot programs for the greenhouse gases, principally the UK ETS.

Creswell (2014) described similar research approaches as pragmatic mixed methods research that utilises both qualitative and quantitative methodologies.

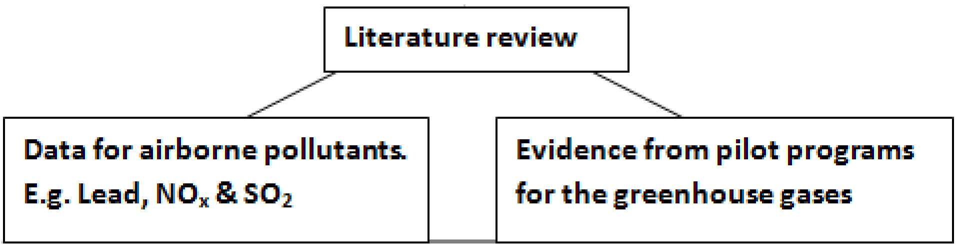

Figure 2: Triangulation of data sources

The triangulation of the data sources as shown above in Figure2 is supplemented by data that has come from institutions that have made observations about the shape of policy for greenhouse gas emissions trading. These are the Organisation for Economic Cooperation and Development (OECD, Paris), the International Energy Agency (IEA, Paris), Resources for the Future (RFF, Washington), Potsdam Institute for Climate Impact Research (Potsdam), the Pew Centre for Climate Change (PCCC, Arlington), the European Commission (EC, Brussels), World Bank (Washington DC) and various other government bodies globally.

3.2 Examples of related research

Early examples of greenhouse gas ETS were from Australia and the UK. In Australia, the NGGAS was established 2003 and in the UK, the UK ETS was established in 2002. It may be said that in these initial projects for greenhouse gas emissions trading existed in a policy vacuum, as there had been no prior models to base policy for greenhouse gas emissions trading upon.

Von Malmborg and Strachan (2005) discuss design factors and their impacts on the constraints of performance (effective operation), acceptance and the ability of market-based environmental policy to reduce emissions. This study uses a case study approach to develop a similar qualitative assessment of tradable permit programs for greenhouse gas emissions trading.

What follows is a review of selected prior studies that have used a comparative policy approach. Aldy et al. (2003) used a framework of six variables to examine thirteen proposals for global climate regimes. Aldy et al. have used a framework that is like the comparative case studies used for this research. While the information provided is of a speculative nature, it finds that the Kyoto protocol was expected to achieve minor environmental outcomes at a disproportionate cost. In terms of climate policy their recommendation was to set modest targets for the initial emissions reductions that could be ramped up over time.

In their book, Harrington et al. (2004) compile data from a group of international authors. This data does not relate to greenhouse gas emissions, it does cover a wide range of market-based approaches to mitigate emissions. For the removal of SO_2 and NO_x emissions, water pollution, leaded gasoline, CFCs and Trichloroethylene (a toxic industrial solvent). Evidence from the US is prominent in the next two examples from the literature. Ellerman et al. (2003) relate the prior experience in the US for several pollutants to the potential application of trade to the greenhouse gases. This study highlights several important design factors. Aulisi et al. (2005) use a narrow comparative study between $SO_2$and NO_x emissions trading, also in respect of potential use for greenhouse gas emissions trading.

The operation of the EU ETS and the RGGI is also the subject of comparative studies in earlier research. Burtraw, Khan and Palmer (2005) conduct an asset value-based evaluation to find that historic allocation of allowances favours the asset owners ahead of auctioning. Engels, Knoll and Huth (2008) comment on the EU ETS's transition from phase 1 to phase 2 with a focus on Norway, Germany the UK and Denmark and the over allocation of allowances in phase 1. They anticipate the behaviour of business as this over allocation is subject of scrutiny in the coming phases.

Some of the underlying principles in the thesis were influenced by the work of Konidari and Mavrakis (2007). At the time they examined a range of environmental policy approaches from various regions, including the EU ETS, to create criteria for a climate change mitigation strategies. The criteria developed were environmental performance, political acceptance, and the feasibility of implementation.

From the US there are some later examples of the comparative research approach, as taken in the thesis, these cover the elements of SO_2 allowance trading that can be transferred to CO_2 allowance trading. Hansjurgens (2011), Chan et al. (2012) and

Schamalensee and Stavins (2013) build on the comparative research technique. In a thirty-year retrospective on Cap and Trade, Schamalensee and Stavins (2015) critique the programs that feature in this study.

In more recent times, two comparative discussions compare the design and performance of operating greenhouse gas ETSs (Narassimhan et al. 2018) and ETS in conjunction with carbon taxes (Haites et al. 2018). Bayer and Aklin (2020) have a counterfactual look at emissions in the EU without having the EU ETS. They argue that despite the early low allowance prices this carbon market has reduced emissions.

At the time of writing, the COVID-19 pandemic has restricted human movement across local and international borders and forced the confinement of people to their homes. Le Quere et al. (2020) suggest that the global greenhouse emission patterns have been influenced on a decadal scale and call for real time monitoring of emissions. An international comparison by Shakil et al. (2020) has found research clusters emerging in four groups, temperature, meteorology, air pollution and the environment. Wang and Wang (2020) consider the analogue between greenhouse gas emissions after the GFC and the potential for a retaliatory rebound post COVID-19.

Table 2 below provides a summary of comparative studies on cap and trade and greenhouse gas emissions.

Table 2: Prior research

Author/s	Year	Title
Aldy, Barrett and Stavins	2003	Thirteen plus one: a comparison of global climate policy architectures
Ellerman, Joskow and Harrison	2003	Emissions trading in the US: experience lessons and considerations for GHGs
Harrington, Morgenstern and Sterner	2004	Choosing environmental policy: comparing instruments and outcomes in the United States and Europe
Aulisi, Farrell, Pershing and Vandeverr	2005	GHG emissions trading in the US States – Observations and lessons from the OTC NO_x budget program
Burtraw, Palmer and Kahn	2005	CO_2 Allowance Allocation in the Regional Greenhouse Gas Initiative and the Effect on Electricity Investors
Konidari and Mavrakis	2007	A multi-criteria evaluation method for climate change mitigation policy instruments
Engels, Knoll and Huth	2008	Preparing for the 'real' market: national patterns of institutional learning and company behavior in the European Emissions Trading Scheme (EU ETS)

Author/s	Year	Title
Hansjurgens	2011	Markets for SO_2 and NO_x – what can we learn for carbon trading?
Chan, Stavins, Stowe and Sweeney	2012	The SO_2 allowance trading system and the clean air act amendments of 1990
Schmalensee and Stavins	2013	The SO_2 allowance trading system: The ironic history of a grand policy experiment
Schmalensee and Stavins	2015	Lessons Learned from Three Decades of Experience with Cap-and -Trade
Haites et al.	2018	Experience with carbon taxes and greenhouse gas emissions trading
Narassimhan et al.	2018	Carbon pricing in practice: a review of existing emissions trading systems
Bayer and Aklin	2020	The European Union Emissions Trading System reduced CO_2 despite low prices
Le Quere et al.	2020	Temporary reduction in daily global $CO_{2\ emissions}$ during the COVID-19 forced confinement
Shakil et al	2020	COVID-19 and the environment: A critical review and research agenda
Wang & Wang	2020	Preventing carbon emission retaliatory rebound post-COVID-19 requires expanding free trade and improving energy efficiency

3.3 Evidence for the design factors in ETSs

The literature review for the research contributed to the development of a basic framework of factors through which the design of programs for greenhouse gas emissions trading could be viewed. The research has elaborated on the factors that have emerged from the literature and additionally from the specific case study material on tradable permit programs.

As these factors were compiled, it was possible to use them in a comparative manner to view several policies that had developed for greenhouse gas emissions trading. It became apparent that not all the factors featured equally in each of the regional cap and trade emissions trading scenarios. For example, the allocation of allowances in each of the case studies was different (Vesterdal & Svendsen 2004).

In the ground-breaking LTP established in 1985, Naughton (1994) felt that restrictions on trading should not be excessive. This aspect relates to the factor of governance (i.e., structures that are in place or may need to be developed). It has come to pass in emissions trading regimes that regulating authorities must have clear legislated authority to implement and enforce the program. Such legislated authority is recognised as the first step to implement later programs, although bipartisan support is needed.

Naughton also recognised that the program must be evasion-proof regarding reporting and the enforcement of penalties. Also, the program should have clearly specified objectives, with an equitable and administratively simple method for allocating the permits. Emission limits should be fairly divided among member states and consistent ground rules applied regarding the creation, banking, and trading of credits.

A fundamental requirement was the need to possess, or develop the technical capabilities to monitor the pollutant, in this case the emissions of oil refineries. Naughton gives the perspective of operating a federally based ETS in the US. In the LTP, emissions management was devolved to the state authorities. Naughton observed many of the factors in this early example of a market-based mechanism that later emerged as basic to the design and operation, appropriate point source. To facilitate cost-effective operation, it was noted that many sources with significant variation in control costs was an optimal feature. As with the greenhouse gases the pollutant had a generalised effect over a large area.

A detailed discussion about the parameters of SO_2 emissions trading in the US is provided in Chapter 4 of this thesis. It is widely believed that the prior SO_2 trading in the ARP is inextricably linked to the subsequent designs for greenhouse gas emissions trading.

Rights to emit the airborne pollutants of NO_x and SO_x were also established in the Californian RECLAIM program, which began in 1993 (Burtraw & Szambelan 2009; Ishikida et al. 2000).

The Norwegian ETS was established in 2005 and was designed to link up with the EU ETS (Saeverud & Wettestad 2006; Ellis & Turpak 2006). The UK ETS was established in 2002 to give the regulators and participants some experience with cap and trade carbon markets (Smith and Swierzbinski 2007). Importantly for this study, the design of UK ETS was used to develop the general methodological approach adopted to examine the specific factors in the case studies.

The literature on tradable permits has also identified elements that were later embedded in the design of the EU ETS. Formative data for this study was adapted from several sources. A paper by Svendsen and Vesterdal (2003) was prepared in response to ten questions raised in the EC Green Paper (European Commission Green Paper 2000) and was a prelude to the design of the EU ETS.

Svendsen and Vesterdal (2003) and Saeverud and Wettestad (2006) reported on the features of schemes that were based in Europe and that targeted CO_2. Generally, these were programs that complied with the flexible mechanisms in the Kyoto Protocol. Woolhouse (2008) suggested some design improvements to the proposed EU ETS, which were for it to encompass both upstream participants (where fossil fuels enter the economy), and downstream participants (where measurement and monitoring are already established). This factor relates to one of the basic components in an ETS (i.e., coverage).

An argument proposed by Svendsen and Vesterdal (2003) suggested that in terms of emission reductions and based on several practical considerations, the stationary energy sector was well placed to implement cap and trade. The sector had background knowledge and experience with the concepts that exist around CO_2 emission reduction that may enhance the likelihood of success with any abatement actions. These researchers were influenced by the US SO_2 trading experience of a market that is a single sector prototype and could provide a basic design upon which to build.

These researchers identified many important design factors, such as the choice of pollutant, the sector or sectors that formed the target group, and the risk of price manipulation across the markets. Also seen as fundamental was the allocation of emission allowances, essentially by grandfathering or auctioning. Complementary policies were starting to emerge as factors for consideration as it was recognised that emissions trading would co-exist with other instruments.

Saeverud and Wettestad (2006) examined the convergence of the operational Norway ETS with the EU ETS, and found the following factors to be fundamental for abatement through tradable permits. They identified phasing in of the program as a factor in terms of the proposed start-up time for emissions trading. Also important was the program scope in terms of the number of greenhouse gases and the enforcement of a non-compliance mechanism, including a potential penalty fee.

In Australia, the NSW NGGAS was a baseline and credit scheme with slightly less onerous parameters, in terms of the level of reductions targeted (fewer allowances) and coverage, when compared to cap and trade more generally (Hemming 2005; Nolles 2007; Outhred 2004).

Other Australian proposals for cap and trade were developed by Shergold (2007), the NETT (2007), and Garnaut (2008) to enhance the literature with potential designs for a greenhouse gas ETS in Australia. The design of the CPRS was considered comprehensive, although it remained untested as the CPRS Bill failed to pass through the Australian parliament in 2010.

In a submission to the Garnaut climate review, the Productivity Commission (2008) suggested that a credible model should share the burden of greenhouse gas abatement across as many sectors as possible. What follows is a synopsis of the reports attributed to Shergold (2007), the NETT (2007) and the Garnaut Review (2008).

In a prime ministerial paper, Shergold (2007) came to focus on price caps, permit allocation, the scope of the program and provisions for alternatives to emissions reduction (i.e., offsets). These basic elements were made more elaborate in the Shergold proposal by the inclusion of targets for long-term emissions abatement that could facilitate a flexible overall emissions trajectory (reduction target).

The paper raised the issue of a forward pricing mechanism to minimise volatility in any carbon allowance market and maximum practical coverage of all sources and sinks. Shergold recommended that permit liability be placed on large facilities and upstream fossil fuel suppliers, with the exclusion of agriculture and land use emissions. Interestingly, it has come to pass that land use is providing much of Australia’s current abatement.

To reduce the initial negative economic impacts, free initial allocation of single year permits, with periodic auctioning of subsequent permits, was the preferred path. The report also detailed a carbon price safety valve, a wide range of carbon offset regimes and the capacity for international linkages.

A summary of the NETT design criteria follows. The NETT (2007) proposals were underpinned by economy wide coverage; stringent compliance measures that included disciplinary measures for non-compliance, a transparent offset process, and permit allocation that does not compromise the schemes ability to achieve a GHG emissions reduction target. The NETT recommended governance structures that exhibited collaborative scheme designs and a coherent climate change strategy.

Sectoral coverage was to include the stationary energy sector, transport, energy intensive industry, and fugitive emissions. A scheme should have a cap (emission reduction target) with suitable emissions reduction trajectories and annual permits to emit one tonne of CO_2-e.

Free allocation of permits was recommended for the stationary energy sector and trade exposed energy intensive industry (TEEII), with auctioning of permits among other participants with a level of equity assistance to disadvantaged parties. Compliance with the process would require the surrender of permits or any offset credits. Offsets would include GHG reductions outside the NETT, as well as the flexible Kyoto mechanisms of JI and CDM.

It was recognised that complex legislative measures would be necessary to facilitate implementation of the NETT. A fundamental requirement would be extensive processes for monitoring, reporting, and verification. It proposed linking with international schemes, complementary measures for agriculture, research into low carbon technology, non-monetary energy efficiency incentives, and climate change adaptation education.

The Garnaut climate change review was established by the Australian Government to “recommend medium to long term policy and policy frameworks” that will shape a response to climate change. The “principles of design” and “intrinsic design features” below are adapted from the emissions trading discussion paper which called for submissions on an ETS (Garnaut 2008, pp. 358-359).

The resulting principles were established to guide design and permit scarcity aligned with emissions target (i.e., demand drives the value of permits). Tradability meant that the characteristics of permits are clearly defined and the mechanism for trade is transparent; credibility related to faith in the enduring nature of critical elements. The principle of simplicity required rules to be easily explained, concessions and exceptions avoided, integration with other markets, and minimal distortions within the domestic scheme relative to international markets.

The climate change review considered the intrinsic design features to be "coverage, offsets, point of obligation, permit design, and permit issuance, international trade and linkages" (Garnaut 2008, pp. 358-359). It was also determined that external price control would be necessary to minimise distortions in the market. The review supported inter-temporality: banking and borrowing to help avoid trade distortions. It called for scheme reviews, strong governance and stringent compliance and penalties.

3.3.1 A framework of design factors for trading

The design factors that have been found to be common across the prior programs are tabled below. The US ARP and the UK ETS are referenced to provide examples of how the factors appear in the schemes. The factors considered in this set of tables are legislation, governance, rules, compliance, allowance allocation, compensation, targets, coverage, and phased introduction.

Table 3: Legislation

Program	Factor – legislation	Date of scheme start – gases covered
US ARP	US EPA Clean Air Act 1990	1995 – SO_2 and NO_x
UK ETS	UK Climate change agreement UK Climate change program	2002 – CO_2

Table 4: Governance

Program	Factor – governance (Governing body)	Nature of participants
US ARP	US EPA	48 US states
UK ETS	Climate Change Authority	Voluntary (downstream participants)

Table 5: Rules

Program	Factor – rules (Administration)	Additions
US ARP	US EPA	Clean Air Interstate rule (CAIR) Cross State Air Pollution Rule (CSAPR)
UK ETS	DEFRA Guidelines	Climate Change Levy

Table 6: Compliance

Program	Factor – compliance (Accounting process)	Penalties
US ARP	US EPA account	US$2000 per ton SO_2 OR NO_x
UK ETS	Self-reporting without verification	na.

Table 7: Allowance distribution

Program	Factor – allowances (distribution)	Issues
US ARP	Grandfathering and auctioning	Fuel switching and innovation (scrubbers) distorted the early operation of the market. Emission reductions were more easily achieved than anticipated.
UK ETS	Grandfathering and auctioning	A high permit price (£53.37 per tonne CO_2)

Table 8: Allowance surplus

Program	Factor – allowances (Surplus)	Subsequent treatment
US ARP	Initial free allocation led to oversupply. Rent seeking behaviour resulted.	The US ARP moved full auctioning of allowances.
UK ETS	Not evident	UK ETS transitioned into EU ETS

Table 9: Targets

Program	Factor – initial targets	Factor – subsequent targets
US ARP	Ten million tons per year reduction from 1980 levels of SO_2 by 2000 by one hundred and ten of the most heavily polluting installations.	Program expanded to cover essentially all fossil fuel installations. Each unit required to reduces emissions by 3.5 million tons per year.
UK ETS	Reduction of 3.8 $MtCO_2e$ (14% of collective baseline of 27.8 $MtCO_2e$)	0.79 $MtCO_2$ for 2002 1.51 $MtCO_2$ for 2003

Table 10: Coverage

Program	Factor – coverage (Industrial sectors)	Gases
US ARP	Stationary energy	SO_2 and NO_x
UK ETS	Large organisations and Medium sized businesses	CO_2

Table 11: Phasing-in

Program	Factor – phasing in (first stage)	Factor – phasing in (second stage)
US ARP	Phase one began 1995.	Phase two followed from 2000
UK ETS	Yearly phased introduction from 2000	2003 and 2003

The framework for the factor comparison was developed in the early stages of the study using data from prior tradable permit programs. These programs ranged from the US LTP that began in 1985 to later developments in the UK, other parts of Europe and Australia. The factors in the preceding tables (Tables 10-18) provide positivistic evidence for the group of nine design factors used in the case study methodology employed in the research. The designs for cap and trade that developed independently of each other still exhibit similar traits and support the group of factors that have been identified as fundamental to emissions trading.

Later in the study each of the nine design factors are compared across the main case studies. This approach illustrates how the design of each program was tailored for each regional situation. It also highlights the differences between the two programs for greenhouse gas emissions trading, such as in the distribution of allowances. Allocation of allowances ranges from free of charge and based on historical emissions, while allowances were also auctioned.

The comparison indicated some similarities between the emissions trading programs for both SO_2 and CO_2, such as the sectors that were covered. In the US ARP, stationary energy was covered, this was generally the case for the greenhouse gas programs. There were also some similarities identified between each program, these included a strong legislative process, clear governance structures, open participant reporting processes and a phased introduction.

3.4 Weighting criteria for the design factors

In the study data from the US ARP (a scheme focussed on emissions reduction), the early development of the United Kingdoms' ETS (a scheme focussed on effectiveness) and the CPRS (a scheme focussed on acceptance) were used as the initial test bed to assign a weighting to the nine ETS design factors that changes depending on how a scheme is focussed on the constraints of acceptance, effective operation and emissions reduction.

The analysis of the US ARP, UK ETS and the CPRS, as mentioned above, indicated that a weighting table could be used to assign a point ranking system to the ETS design factors, i.e., legislation, rules, targets, compliance, coverage, allowance allocation, governance, phasing-in and compensation.

A scale of 0-1-2 was used, 0 equates to a weak alignment to a constraint and 2 indicating a strong alignment. In relation to the main constraints identified in the study, each of the factors are ranked in relation to the whether the factor had appeared in the original design and how the factor original or not, had impacted on the program.

The set of questions that were used to rank each factor in terms relation to the constraints were:

1. Did the factor appear in the original design of the program?
2. Is there a specific rule or set of rules that apply to the factor?
3. During the reporting period has the impact of the factor grown in prominence.
4. Across the study does a factor's association with the constraints of acceptance, effective operation, and emission reductions correlate?

The first weighting question asks if after careful consideration the designers of the program felt that the factor was considered a fundamental element in the program, such as governance in relation to the constraint of effective operation.

Some factors are more complex than others and require definition through a set of rules. The second weighting question reflects the criticality of a design factor. An example from the weighting tables is the factor of compensation in terms of acceptance.

In the conceptual framework for the study, it is acknowledged that circumstances change, and external factors shape the programs in unanticipated ways. Weighting question three assigns value to a factor as it is perceived to have grown in prominence. Legislation gets a high score in its alignment with emissions reduction constraint.

The final weighting question four, seeks to understand if there are factors that are aligned to more than one constraint. A strong score for this question is an indication that the factor has a role to play in the cohesiveness of the program. In an anticipated outcome rules and legislation fall into this category.

After testing the process for factor weightings in the US ARP, UK ETS and the CPRS a similar technique is later applied to the two main greenhouse gas case studies. Each of the nine principal design factors are considered in the Tables 12-17 below in relation to their link to the main constraints that have been identified, namely acceptance, effectiveness and emission reduction.

An average figure was derived for each constraint and the nine design factors then fall above or below this average. The design factors that received weightings that were higher than the average for a constraint are considered as strongly aligned to a constraint. While the factors that were weighted lower than the average, are less strongly aligned to a constraint.

3.4.1 Criteria tables for factor weighting

Table 12: Weighting table for acceptance (strongly aligned factors)

Factor	Compensation	Coverage (wide)	Legislation
Weight for criteria 1	2	2	1
Weight for criteria 2	2	1	1
Weight for criteria 3	1	2	0
Weight for criteria 4	1	0	1
Totals	6	5	3

Table 13: Weighting table for acceptance (less strongly aligned factors)

Factor	Phasing in	Targets	Allowance allocation	Rules	Governance	Compliance
Weight for criteria 1	1	1	1	0	1	0
Weight for criteria 2	0	0	0	1	1	0
Weight for criteria 3	1	0	0	0	0	0
Weight for criteria 4	0	1	0	0	0	0
Totals		2	1	1	2	0

The averaging of total values for the factor weightings shown above in Table 23 and Table 24 indicate that the value to determine a factors strength of alignment to the constraint of acceptance was, 2.4.

Table 14: Weighting table for effective operation (strongly aligned factors)

Factor	Governance	Compliance	Legislation	Rules
Weight for criteria 1	2	2	2	1
Weight for criteria 2	2	1	2	1
Weight for criteria 3	2	1	0	1
Weight for criteria 4	1	1	0	1
Totals	7	5	4	4

Table 15: Weighting table for effective operation (less strongly aligned factors)

Factor	Targets	Allowance allocation	Phasing in	Compensation	Coverage
Weight for criteria 1	1	1	1	0	1
Weight for criteria 2	1	1	0	1	0
Weight for criteria 3	1	0	1	0	0
Weight for criteria 4	0	0	0	0	0
Totals	2	2	2	1	1

The averaging of total values for the factor weightings shown above in Table 25 and Table 26 indicate that the value to determine a factors strength of alignment to the constraint of effective operation was, 3.1

Table 16: Weighting table for emissions reduction (strongly aligned factors)

Factor	Legislation	Rules	Targets	Compliance
Weight for criteria 1	2	1	2	1
Weight for criteria 2	2	1	2	1
Weight for criteria 3	2	2	1	1
Weight for criteria 4	2	2	0	1
Totals	8	6	5	4

Table 17: Weighting table for emissions reduction (less strongly aligned factors)

Factor	Coverage (narrow)	Allowance allocation	Governance	Phasing in	Compensation
Weight for criteria 1	1	1	1	0	0
Weight for criteria 2	0	1	0	1	0
Weight for criteria 3	1	0	0	0	0
Weight for criteria 4	1	0	1	0	0
Totals	3	2	2	1	0

The averaging of total values for the factor weightings shown above in Table 27 and Table 28 indicate that the value to determine a factors strength of alignment to the constraint of emissions reduction was, 3.4.

From the preceding tables, the common factors of scheme design are ranked to see how they affected three prior designs, the CPRS, UK ETS and US ARP. In these prior designs the nine design factors are considered in relation to their strong or weak alignment to the three constraints. Several predictable trends can be observed in each of the constraint groups. For example, the make-up of the three more strongly aligned factors in the group that are important to gain acceptance of greenhouse gas emission trading schemes.

In the summary Table 18 shown below it can be seen that they are compensation, wide coverage, and legislation. The study shows that these factors may have a negative trade-off effect in relation to the mitigation of greenhouse gas emissions. The literature provides a level of support for wide coverage to promote burden sharing and lowest cost abatement.

The design factors that are more strongly aligned with the constraints of effectiveness and emissions reduction are shown in the study to similar. For the constraint of effectiveness, these factors are governance, compliance, legislation, and rules. For the constraint of emissions reductions in order, are legislation, rules, targets (or caps) and compliance.

For the constraint of emissions reduction, the design factors at the weaker end of alignment scale may provide an insight into achieving, or not, the greenhouse gas mitigation goals with a quantity based instrument to determine a carbon price. In order of weakest to slightly stronger, these factors are compensation, phased introduction, governance, allowance allocation and a narrow coverage.

The argument that follows is that the design factor of compensation is most damaging in terms of the underachievement of emissions reductions. At the top end of the weakly aligned factors, narrow coverage sits on the verge of being a more strongly aligned factor. This borderline classification is likely to be a result of regional variations between schemes. The propositions are tested in the comparative case studies in Chapter 5 on the EU ETS and Chapter 6 on the RGGI.

Table 18: Factor strength of alignment with the constraints

Alignment (9 = strong) (1 = weak)	Factor alignment in a scheme focussed on the constraint of acceptance (Based on the CPRS)	Factor alignment in a scheme focussed on the constraint of effectiveness (Based on the UK ETS)	Factor alignment in a scheme focussed on the constraint of emissions reduction (Based on the US ARP)
9	Compensation	Governance	Legislation
8	Coverage (wide)	Compliance	Rules
7	Legislation	Legislation	Targets
6	Governance	Rules	Compliance
5	Phasing in	Targets	Coverage (narrow)
4	Targets	Allowance allocation	Allowance allocation
3	Allowance allocation	Phasing in	Governance
2	Rules	Compensation	Phasing in
1	Compliance	Coverage (wide)	Compensation

From Table 18 above, in relation to the constraint of acceptance, the most strongly aligned factors are compensation, coverage, and legislation. For the constraint of effective operation, the strongly aligned factors are governance, compliance, legislation, and rules. In achieving emissions reduction, these factors are legislation, rules, targets, and compliance.

Initially in the study, evidence was sought for emission reductions in the case studies directly from the program databases. Emission reductions are limited to the direct participants in the programs, which may support other complementary policies.

In the later stages of the study, annual reports became available from the governing bodies. To supplement these reports other sources have become available, e.g., research by various expert bodies and experienced researchers.

There is acknowledgement of the downward pressure that the GFC has had on emissions (Schamalensee & Stavins, 2015; Bayer & Alkin, 2020). Considerable interest is emerging in relation to the COVID 19 pandemic and global greenhouse gas emissions and the potential of an emissions rebound (Wang & Wang, 2020; Le Quere et al. 2020; Shakil et al. 2020). The GFC and COVID 19 related research is briefly discussed in the comparison carried out in Chapter 7.

3.5 Gathering the EU ETS emissions data

Over the first two phases of the EU ETS (2005 to 2012), publicly accessible reports were available via the Europa website through the EUTL (previously the CITL). In conjunction with publication of the EUTL, the emissions and compliance were verified by the UNFCCC (Europa 2012). In the early stages of the EU ETS, the EUTL served primarily as a collection point for the NAPs developed by each of the participating countries.

Each emissions source in the EU ETS was given a unique identifying number, which was used in the verified emission reports. The countries that were submitting data for the EUTL were required by the EC to have had an independent accredited verification carried out on their emissions data. The EUTL also provided reconciliation of allowance allocations and allowance surrender data. The EU carried out its own evaluation of this information before seeking external verification from the UNFCCC. When the validity of the reported data was established, the EC then published the verified compliance data for each liable entity country on the Europa website.

Phase one of the EU ETS ran from 2005 to 2007 and, in terms of the emissions and compliance data, this phase was important to establish the first data collection methodologies. The data collection in the first phase was without precedent and improved as experience grew into the second phase. For the purposes of this study, facility level emissions data was available in the form of an excel spreadsheet that summarised data from 2005 to 2011.

In 2009, the national registries were replaced by a single EU wide registry and the CITL (EUTL) later became known as the European Union transaction log (EUTL). At the time of writing, all thirty-one countries participating in the EU ETS were registered on the EUTL.

Phase 2 of the EU ETS took in 2008-2012 and coincided with the first commitment period of the Kyoto Protocol, where the countries participating in the EU ETS had a concrete target of eight percent to meet. In Phase 2 three new countries joined and it featured a lower cap compared to the 2005 cap (-6.5%) (European Commission 2020).

In Phase 3 (2013 to 2020), the stationary installations that are participants include power stations and other combustion plant with greater than 20MW capacity. Around 12 industrial sectors are covered including aviation. In 2018, it was reported that the EU ETS had 10,744 permitted installations. This study uses the summary data on Phase 2 and Phase 3 as supplied by the European Commission (2020).

Not all the participating EU countries were able to provide complete verified emissions data for both phases of the EU ETS that were examined. Three countries were unable to provide complete data sets and, as a result, some phase one data has been left out of the sample.

The sources for the price discovery data in the EU ETS are shown in Appendices A1, A2 and A3. This price discovery data for the EU ETS carbon markets comes from several sources. These are Benz and Henglebrock (2008), who produced a report on liquidity and price discovery in the European CO_2 futures market using an intraday trading analysis, the *Journal of Chemical and Engineering News* (2012) and the EUTL (2020).

The carbon prices that emerge have been historically low and critics of cap and trade point to the low prices as evidence that the markets do not work in the mitigation of greenhouse gases. Bayer and Aklin (2020) are among the observers that say the low prices are a result of an oversupply of allowances. They estimate that within the EU ETS between 2008 and 2016 there was an emissions reduction of 1.2 billion tons or 7.5% of emissions covered by the scheme.

The country level emissions data sample from the EU ETS was totalled to provide an indicator of the overall EU ETS emissions. It became apparent in this cumulative comparison that, for a period, the emissions were falling, following a similar trajectory to the GDP in the region in the wake of the GFC.

3.6 Gathering the RGGI emissions data

In the RGGI program, the COATS is at the heart of reporting on the verified emissions of participants. Several public reports that have first been verified by the US EPA are available from the COATS. In 2009, the US EPA included the RGGI under the Part 75 rule that was established in Volume 40 of the Code of Federal Regulations in 1993 to explain continuous emissions monitoring for the US ARP.

An example is the quarterly emissions report that provides data on unit and facility level emissions for the first control period from January 2009 to December 2011. From these reports, an excel spreadsheet was used in this study to determine the emissions of a group of facilities over the first compliance period in the RGGI. Each registered participant in the COATS system has a unique identifier, called the ORIS code. A search engine is provided that can filter results for a facility using the ORIS code number. Overall facility level or unit level reports can be obtained on an annual or multi-year basis. Participants are stationary energy sources with a generation capacity more than 25MWs.

The RGGI has had three subsequent control periods, the second 2012 to 2014, a third 2015 to 2017 and the current control period January 2018 to December 2020. The CO_2 emissions data from the COATS covering the second and third control periods is obtained in excel spreadsheets on a state by state basis showing total annual emissions.

3.7 Chapter summary

As the research progressed, the methodology developed in an prospective manner as new data was introduced. Initially, a wide view was taken across the existing tradable permit literature. As the contextual background for the research became clearer, the research questions became more focused.

Research Question 1 sought to establish if, as expected, the lessons from the successful US ARP could be applied to the greenhouse gas ETSs, as a cornerstone of the UNFCCC Kyoto Protocol. To answer this question the next chapter, Chapter 4 examines details of the US ARP. Chapter 7 is used to compare all the case studies looking for shared traits and distinguishing features.

The UNFCCC provides a validity check of the EU ETS data, as does the US EPA in the case of the RGGI. The program databases also list information about the compliance status of each participating entity, whether complying or non-complying.

The remaining two research questions relate to the identification of design factors and determine how the design factors have affected greenhouse gas ETS. The study examines the interaction that is taking place between the design factors and the constraints of acceptance, effectiveness, and emissions reduction.

The sectors covered by an ETS are important to both cost-effectiveness and efficiency. In the EU ETS case, Svendsen (1998) suggested that all fossil fuel-based utilities with a capacity of more than 25 mega-watts (MWs) should participate, along with an opt-in alternative for other firms.

For the purpose of the study, prior complementary policies and the underlying economic circumstances in a region are considered external factors, although they have been found to be important when designing programs for greenhouse gas emissions trading.

Chapter 4: Knowledge transfer from the US ARP

4.1 Introduction

This section of the thesis examines how the designs that have emerged for cap and trade greenhouse gas emissions trading have been shaped by the experience with emissions trading for SO_2 in the US ARP. The US ARP targeted airborne deposition of SO_2 and NO_x and applied to electricity generators across the US from 1995, under amendments of the US EPA CAA of 1990. The US ARP was considered a success in cost-effectively reducing the impact of acid rain in the US (Ellerman et al. 2000).

Generalisations were made about the US ARP and its ability to influence later designs for CO_2 emissions trading. While the scope of global greenhouse gas emissions trading was more challenging, activities associated with SO_2 reductions across the US under the ARP led to great expectations. Hansjurgens (2011) has found that there was strong support for the notion that tradable permit programs would be well suited to a reduction of emissions in the suite of the greenhouse gases.

Between 1995 and 2004, the US ARP had operated efficiently to reduce emissions. After this time, in 2005, two natural disasters, hurricane Katrina (August) and hurricane Rita (September), were estimated to have caused damages in the order of US$120 billion. Weather conditions in the US during 2005 and a coal train derailment in Wyoming that impacted the supply of low sulphur content coal saw the spot price of coal rise in 2005 by 220% (Ellerman et al. 2008).

At the end of 2005, the US ARP allowance prices had reached a record high level of US$1,550 per short ton. Stavins (2013) suggest that thereafter cap and trade was given the unpopular nickname of cap and tax as the price of allowances rose. After this period, a change in US EPA legislation was drafted, to act in concert with the ARP that saw the introduction of the clean air interstate rule (CAIR).

The CAIR would require greater emission reductions from power plant operators in the eastern US states and the sources of emission in these states began banking allowances. The CAIR took effect in 2011 covering power plants in 28 eastern states while the US

ARP remained in place covering all power plants in the US. The CAIR was, in 2015, superseded by the cross-state air pollution rule (CSAPR) (US EPA 2013b).

Importantly for the participants, coal fired electricity generators, there was some clarity regarding SO_2 emission reduction technologies. A key element identified in the US ARP was the cost-effectiveness of the process. The abatement costs were minimised as the participants covered by US ARP made their own decisions about the least expensive manner by which to reduce emissions. These decisions related to fuel switching, scrubbing technologies and the closure of older installations.

A strong link has been found in relation to the phased introduction of SO_2 emissions trading. A phased introduction relates to the targets for emissions reduction and the proposed coverage, either of which can be increased in a staged manner.

As the experience with the US ARP and SO_2 emissions trading grew, so too did the level of understanding about the important elements of the program. Other correlations related to the accurate measurement of emissions and the initial free issuance of some allowances.

The phenomenon of global warming has forced the measured deployment of greenhouse gas emissions trading. A significant element of this study, the EU ETS was closely aligned to the objectives of the UNFCCC and the Kyoto Protocol (Newell, Pizer & Raimi 2013). It was an early attempt at a coordinated multi-country program to mitigate greenhouse gas emissions. From its commencement to the present, the EU ETS has faced several problems that have threatened to derail the process. The solutions to these problems are identified in the study as the factors that are important during implementation of GHG emissions trading.

The other main case study, the RGGI, was a US regional approach to the same problem of global warming. The RGGI developed from a climate action plan that over time became the RGGI model rule and was more closely aligned to a familiar model for cap and trade. It was influenced by earlier tradable permit programs for airborne pollutants (Holt et al. 2007). These other pollutants included lead, SO_2 and NO_x.

The aim of this chapter is to compare the data from each of the greenhouse gas programs studied with an assumption made about the transfer of experience from the US ARP; then to comment on the discovery of the design factors found in the study that are used in the comparative framework. This part of the discussion examines the relevance of the factor comparison that was developed for the study and the use of this framework to compare CO_2 and SO_2 emissions trading.

4.2 The transfer of knowledge from SO2 trading to CO2 trading programs

The literature suggests that in terms of the acceptance of emissions trading, the US ARP received wide support. This was unique in the US for a market-based environmental policy. Stavins (1998, p. 76) questioned: “Given the historical opposition to market-oriented pollution control policies, how can we explain the adoption of the SO_2 allowance trading program in 1990? More broadly, why has there been increased openness to the use of market-based approaches?”

Some unexpected aspects of the SO_2 trade were the health benefits that appeared earlier than the environmental benefits. Also, the deregulation of the railways provided low sulphur coal and a perverse rent seeking behaviour was encouraged by an over allocation of allowances.

Stavins indicates that the answers are related to a set of issues unique to the US at the time. They included the concentration by economists on cost effectiveness, the high cost of emissions abatement, an aging power station plant profile and the support of a strong environmental group.

The US ARP, it is said, met with opposition from some participants who felt that a tax-based system would entrench an established market position and create a barrier for new entrants (Nye & Owens 2008). When the use of market forces for environmental purposes has been proposed, there has been some scepticism about the level of political motives driving the “new environmental policy instruments” (Von Malmborg & Strachan 2005, p. 144).

Several forces make these fiscally responsible policies more popular. These include the politicisation of the environment, broad economic downturns, and the perceived need of policy makers to respond to the corporate desire of being ecologically responsible (Bailey & Rupp 2004).

This study has identified that much has been learnt from the US ARP and that experience with emissions trading for SO_2 could potentially have direct input into the design of trading schemes for CO_2. A few years after the ARP began in 1995 began; a paper emerged that began the early discussion about the topic. In *What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading,* Stavins (1998) reflects on the merits of ARP and identifies many of the key design features.

Burtraw (2002) suggested that another important reference book: *Markets for Clean Air: The US Acid Rain Program*, was paving the way for developing trading schemes for the greenhouse gases. In this book, the authors' state:

> Chapter 12 offers concluding observations and presents some thoughts on the implications of the experience with the SO_2 trading program for the application of similar market-based emission-control approaches to other pollutants, such as air emissions that are thought to contribute to global warming. (Ellerman et al. 2000, p. 21)

Many research papers have been published that suggest that the positive experience with the US ARP and the trading regime could be transferrable to greenhouse gas emissions trading. The US EPA also highlights that, "Public availability of data, or information transparency, is a vital feature of the ARP" (Napolitano et al. 2007, p. 55). Several research efforts have suggested that elements of the US SO_2 SAP would be transferable to a program for greenhouse gas emissions trading. These include Chan et al. (2012), Hansjurgens (2011), Burtraw et al. (2005), and Ellerman, Joskow and Harrison (2003).

The US EPA suggested that under the US ARP, from 1995 to 2010, SO_2 emissions from electricity generation plants had greatly reduced. "Under the Acid Rain Program, the electric power sector's SO_2 emissions were capped at 9.05 million metric tons for the year 2000. The cap was to gradually decline to 8.14 million metric tons per year in 2010" (US EPA 2007).

In 2005, the US ARP was supplemented by the cross-state acid pollution rule (CSAPR), the combined ARP–CSAPR has reduced SO_2 emissions in the period 2005-2016 by 85% (US EPA, 2019).

The initial US EPA cap for 2010 emissions was 8.95 million tonnes, which was around half of the stationary energy sectors' emissions of SO_2 in 1980 (US EPA 2011). The determination of the US ARP cap varied from time to time depending upon seasonal forecasts and plant profiles.

The literature in this study reveals the design factors inherent in the US ARP that are responsible for its success. In a chronological progression through the literature, some of the salient features of the tradable permit program are revealed. This data is later summarised according to whether evidence can be found for them in both the EU ETS and the RGGI.

4.2.2 Comparing the GHG ETS case studies and the US ARP literature

A grouping of factors was determined by examining this prior literature and identifying the distinct traits that the authors have observed about SO_2 emissions trading. The collected data presents a synthesis of factors relevant to the study of greenhouse gas emissions trading. The task of assembling this data used some of the common themes that emerged from the traits of SO_2 and GHG emissions trading. For example, the evidence from Tietenberg et al. (1998) and Stavins (1998) suggested that there would be a relatively short, but significant, list of factors to consider.

Tietenberg considered that emission caps, allowance trading, compliance and stringent environmental standards were fundamentally important. Stavins expanded on this, to include a phased introduction and cost-effectiveness in trade between facilities, as well as acknowledging that the banking of allowances and compliance encouraged by a US$2000 per ton penalty were important.

Of the above factors that were sourced from Stavins' deliberations on the US ARP and SO_2 emissions trading, most had identifiable links to the features of the greenhouse gas emissions trading. The phased introduction of US ARP SO_2 emissions trading was more strongly mirrored in the EU ETS. In the case of the US ARP, a phased introduction related to the targets for emission reductions that were increased in a staged manner. It was noted by Stavins and many other observers that the emission reduction targets in the US ARP were achieved. Stavins also felt that while the original motivation was the mitigation of acid rain, human health improved as a complementary outcome.

As the experience with the ARP and SO_2 emissions trading grew, so too did the level of understanding about the important elements of the program. This was evident in the work of Ellerman, Joskow and Harrison (2003), and Burtraw et al. (2005), all of whom have contributed to a deeper understanding of the process. Noted in the contribution of Ellerman, Joskow and Harrison is success in lowering the cost of meeting emission reduction goals and the enhanced achievement of environmental goals. These authors also observed that allowances were clearly defined to allow trade without case-by-case verification, and that banking improves economic and environmental performance. Their remaining observations related to the targeted electricity sector, accurate measurement of emissions and the free issuance of initial allowances.

Burtraw et al. (2005) provided a detailed account of the important factors for SO_2 trading in the US ARP. They favoured the cap that was fixed annually, and which was, in the case of the US ARP, ultimately to cap the allowance allocation at 8.95 million tons by 2010. A single national market was adopted after the regional model failed due to high administration costs. As an aside, in the US ARP it was noted that environmental improvement was realised more slowly than the unexpected public health benefits were.

Burtraw et al. (2005) suggested that the largest and dirtiest facilities could reduce emissions with the least cost and, that during phase two, the cost savings were estimated to be 43% of compliance costs. Inherent flexibility was, they believed, exhibited through switching to low sulphur coal and that cost reducing innovations were supported through savings. Another important statement suggests that a measure of efficiency is the convergence of the marginal cost of abatement to the price of allowances in the market.

The comparative study on two programs for greenhouse gas, i.e., the EU ETS and the RGGI develops a set of tables below (Tables 19-25), that reveal how the programs for greenhouse gas reflect the principles raised in a few the research reports about the US ARP.

The research reports cover a substantial body of material which can be viewed in two chronological periods. The first group of papers are post start-up of the US ARP and pre the Kyoto Protocol coming into force. The reports are described here as Group 1 and have publication dates that range from 1998 to 2005. The material in Group 1 comes from: 1) Tietenberg (1998), 2) Stavins (1998), 3) Ellerman, Joskow and Harrison (2003), and 4) Burtraw et al. (2005).

The second collection, Group 2 are post the Kyoto Protocol coming into force and were published between 2011 and 2013. The research material in Group 2 comes from: 5) Hansjurgens (2011), 6) Chan et al. (2012), and 7) Schmalensee and Stavins (2013). A common theme amongst Group 2 is reflection on greenhouse gas emissions trading considering the antecedent US ARP.

A reduction of emissions in the EU ETS and RGGI case studies would reflect the experience with emission trading in US ARP. It was assumed that the previous experience in the US ARP would influence the design of subsequent programs. Also, that a similar group of design factors used in the US ARP would feature in GHG ETSs

Table 19: Features of SO_2 trades applicable to CO_2 trades, Tietenberg et al. 1998

Origins of report or paper	**Report – United Nations Conference on Trade and Development (UNCTAD). Title: International Rules for GHG Emissions Trading. Defining the principles, modalities, rules and guidelines for verification, reporting and accountability.**
1. Emission caps. 2. Allowance trading. 3. Reduced cost of compliance. 4. Compliance. 5. Stringent environmental standards. 6. Rules for monitoring reporting and verification. 7. Intra and inter facility trades. 8. Penalties for non-compliance (fines and forfeiture of allowances). 9. Self-reporting to public database. 10. Small number of allowances auctioned. 11. Fostered innovation.	

Table 20: Features of SO_2 trades applicable to CO_2 trades, Stavins 1998

Origins of report or paper	Journal article – *The Journal of Economic Perspectives.* Title: What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading.
1. Phased introduction.	
2. Cost-effectiveness results from trade between facilities.	
3. Banking of allowances.	
4. Compliance encouraged by US $2000 per ton penalty.	
5. Targeted emissions reductions achieved.	
6. While the original motivation was the mitigation of acid rain, human health improved.	

Table 21: Features of SO_2 trades applicable to CO_2 trades, Ellerman, Joskow and Harrison 2003

Origins of report or paper	Report – Pew Centre on Global Climate Change. Title: Emissions Trading in the US. Experience Lessons and Considerations for GHG.
1. Success in lowering the cost of meeting emission reduction goals.	
2. Enhanced the achievement of environmental goals.	
3. Allowances are clearly defined to allow trade without case by case verification.	
4. Banking improves economic and environmental performance.	
5. Targeted electricity sector.	
6. Accurate measurement of emissions.	
7. Majority of allowances issued free.	
8. Allowance market was slow to develop due to external forces.	

Table 22: Features of SO_2 trades applicable to CO_2 trades, Burtraw et al. 2005

Origins of report or paper	Discussion paper – Resources for the Future. Title: Economics of Pollution Trading for SO_2 and NO_x.
1. Fixed annual cap.	
2. Allowance allocation ultimately capped at 8.95 million tons in 2010.	
3. Single national market adopted after regional model was dropped due to cost considerations.	
4. Environmental improvement slower to be realised than the public health benefits were.	
5. Largest and dirtiest facilities could reduce emissions most easily.	
6. During phase two the cost savings estimated to be 43% of compliance costs.	
7. Inherent flexibility facilitated fuel switching.	
8. A measure of efficiency is the convergence of the marginal cost of abatement to the price of allowances in the market.	
9. Supported cost reducing innovations.	

Table 23: Features of SO_2 trades applicable to CO_2 trades, Hansjurgens 2011

Origins of report or paper	Focus article – WIREs Climate Change (John Wiley and Sons 2011). Title: Markets for SO_2 and NO_x – What can we learn for carbon trading?

1. Initial coverage in phase one was less than phase two coverage.
2. Ultimate cap approximately 50% of 1980 emissions.
3. A share of allowances removed from the market to cater for new entrants.
4. Trading volume was initially low then increased at later stages.
5. Price volatility due to excess allowances and innovative controls.
6. Cost-effectiveness difficult to assess as there is no reference case.
7. Environmental performance exceeded expectations.
8. Bigger is better.
9. A large range of participant abatement cost results in more efficient markets.
10. Banking increases temporal flexibility.
11. Price fluctuations should be anticipated in market design.
12. Auctioning may be superior to free allocation.
13. Bigger markets increase transaction costs.
14. Clear rules required for monitoring, reporting and verification.
15. Rent seeking behaviour encouraged by over allocation of allowances.
16. A decentralised (state based) system may have benefits due to the large number of sources.
17. Scheme design should allow for later modifications.

Table 24: Features of SO_2 trades applicable to CO_2 trades, Chan et al. 2012

Origins of report or paper	Report – Harvard Environmental Economics program. Title: The SO_2 allowance trading system and the Clean Air Act amendments of 1990. Reflection on Twenty Years of Policy Innovation.

1. Penalties for non-compliance set in statute.
2. Penalties for non-compliance significantly higher than anticipated compliance costs.
3. External factors (e.g., railroad deregulation) resulted in low cost low sulphur coal.
4. Banking allowed smoothing of allowance price variations.
5. Older facilities disadvantaged as compared to newer facilities built under more stringent standards.
6. Original scheme design was guided by heuristic (trial and error) analysis.
7. Expensive monitoring in real time was initially opposed but proved beneficial to some participants.
8. Action to reduce emissions in one region had benefits for geographically distant areas.
9. Local and state regulation was important to avoid so called hot spots.
10. Technology was available (scrubbers) to remove sulphur from emissions.
11. Additional innovative solutions were found (e.g., mining techniques).
12. In the US senate the political support of the Bush administration (of 1989) was underpinned by significant academic rigour.
13. The stakes are higher in addressing CO_2 than they were for the SO_2 program.

Table 25: Features of SO_2 trades to CO_2 trades, Schmalensee and Stavins 2013

Origins of report or paper	Journal article – *The Journal of Economic Perspectives*. Title: The SO_2 Allowance Trading System: The Ironic History of a Grand Policy Experiment.
1. Free allocation of the initial allowances. 2. Moderate coverage of single sector (electricity) during phase one. 3. Wider coverage of single sector (electricity) during phase two. 4. Target for emissions cap set at 'elbow' point where abatement costs anticipated to be relatively low. 5. Free initial allocation of allowances. 6. Banking permitted. 7. Cost saving estimated to be at least 15% over traditional command and control measures. 8. Environment did not recover as quickly as predicted. 9. Unforeseen health benefits. 10. Railway deregulation provided cheaper low sulphur coal. 11. Conceptual aspects of cap and trade confused between two main parties. 12. Threat of policy reversal due to changing political landscape. 13. Early low allowance prices remained stable for a decade. 14. Later allowance prices spiked when rules where modified. 15. State level regulations eventually superseded national rules.	

By comparing the common elements from the tables above for a trade in SO_2 allowances, it is possible to list features that appear to have resonance for a trade in CO_2 allowances. These features include stringent caps, trades between facilities, banking, and cost effectiveness as the marginal cost of abatement converges to the price of allowances.

The phasing in of targets, an initial free allocation of allowances, widening of the scheme coverage and penalties for non-compliance also feature in the SO_2 trades. There was an inconsistent message that emerges in relation to whether bigger is better versus the targeting of a single sector to promote efficiency. While the cap and trade market tended to foster innovation, the newer facilities benefited over older facilities in relation to the implementation of new technology.

4.3 Carbon taxes, complementary policy and governance

The use of tradable permits is known as a quantity-based approach as it, in theory, sets an absolute limit on the level of emissions (i.e., a target). In choosing a market-based mechanism the governing body could also, as was tried in Australia and several other countries, use a price-based method to set a carbon price. This is done by introducing what has become known as a carbon tax.

As an alternative to greenhouse gas emissions trading, a tax on emissions has been previously discussed in the literature review carried out for this research. To recap, McKitrick suggested that the outcome of emissions trading or an emissions tax could be the same. He stated, “the policymaker can control either price (i.e., set a tax on emissions) and let the market determine the quantity or control the quantity (by issuing a set number of permits) and let the market determine the price. Either method can generate the same outcome” (McKitrick 2011, p. 34).

For regulators to consider the case of large base load electricity generators, the difference between a tax or cap and trade is related to the mix of fuels that are used in a region (e.g., coal, gas, combined cycle or nuclear). Green (2007) suggested that where coal is the dominant fuel, then cap and trade can be shown to be more cost-effective; whereas when lower emission fuels are favoured then a carbon tax is the most efficient. Pezzey (2006) found that for a mixed fuel scenario, a price threshold may be applied when a move from cap and trade to a mix of trade and tax is efficient at a price point.

It became apparent during this study that regional differences can affect the design choices for a system that is meant to respond to climate change. These differences can relate to a range of economic and political anomalies, such as comparative advantage, the mix of fossil fuels, renewable energy choices and political alliances.

The US ARP has, by way of comparison, had aggressive reduction targets. The targets in programs for CO_2 reductions became more benign when a global recession corresponded with their introduction. Complementary policies also reflect regional differences, especially in the case of the US ARP. The nature of the threat from the deposition of acid was not evenly distributed across all the regions covered. As a result, additional rules were developed to cover interstate anomalies.

In the US ARP, the EU ETS and the RGGI there were existing governance bodies: the US EPA, the EC, and the NEG-ECP, respectively. In the case of the RGGI, a new body also developed, RGGI Inc. At start-up of the EU ETS and the RGGI, a degree of decision making was ceded down to either the national level (EU ETS) or the state level

(RGGI). As the programs have progressed and expanded there has been a tendency to favour centralised decision making, where possible.

Alternative emissions reduction policy remains fundamentally important for greenhouse gas emissions trading, potentially reducing the market-driven cost-effective operation of a cap and trade regime. As Carlson (2012, p. 1) said:

> Complementary policies, by contrast, designate in advance how greenhouse gases ("GHGs") must be reduced and the sources from which these reductions must come. While complementary policies can effectively reduce emissions, they also constrain the market options available under cap and trade by limiting the choices emitters have about how to reduce their emissions. That constraint can lead to higher compliance costs.

A key element identified from the experience of greenhouse gas emissions trading, is the cost-effectiveness of the process. At the time of writing the price signals that have come from the various carbon markets indicate that a relatively low and stable price for allowances can be achieved, Chapters 5 and 6 to follow elaborate on these price signals.

The abatement costs are minimised as the participants covered by an ETS make their own decisions about the least expensive manner by which to reduce emissions. An alternative to greenhouse gas emissions trading is to introduce an environmental tax. It is widely believed that the crucial decisions about the level of such a tax are usually made by regulators who may not be well placed to determine marginal costs of abatement.

4.4 Chapter summary

It has been argued that the US ARP, a successful trading program in SO_2, would reveal design factors that would be useful in designing programs for greenhouse gas emissions trading. The study has found characteristics of SO_2 allowance trade that can be considered as having contributed to emissions reduction, these are: easily identified sources, established monitoring techniques and importantly, readily available reduction options.

The first two characteristics easily identified sources and established monitoring techniques have been found in the existing designs for greenhouse gas ETSs. Unfortunately, the third characteristic, readily available reduction options, has not been as apparent.

Assumptions have been made that relate to anticipated reductions in the level of greenhouse gas pollution that will, overall, be emitted from the emissions sources in each of the case studies. This assumed reduction in emissions would reflect the experience with emission trading in the US ARP. The study of the EU ETS and the US RGGI has shown that a high level of compliance from the participating industrial sectors can be achieved. The data collected on the current phases of each program suggests that this compliance has translated into emissions reductions.

This study has benefited from the lengthy prior observations on the US ARP. It has been established that the principles of SO_2 emissions trading have been applied to the trading program for CO_2. The comparison between the US ARP and the later programs for greenhouse gas emissions trading reveals a tendency toward the interchangeability of design factors between the programs. Most, but not all, of the factors that were identified as important for emissions reduction in the SO_2 trading program, also appear important in greenhouse gas emissions trading.

The specific data from the case studies that appears to correlate with this evidence from the pre Kyoto and post Kyoto groups of literature relate to the following: clear definition of allowances, the banking of allowances, a high level of compliance, rules for verification, monitoring and reporting, self-reporting to a public database, cost-effectiveness, flexibility of original design to account for changing external forces, a decentralised system for administration, a centralised system for governance, and a phased introduction.

There are several factors from the evidence about SO_2 allowance trading that did not show a strong correlation to the main greenhouse gas case study data. These were: the identification of positive environmental and health outcomes, establishing a base case to assess cost-effectiveness, and heavy penalties for non-compliance.

The visible effects of acid rain provided a strong impetus for the cutting of SO_2 emissions using the US ARP. The tangible impacts of global warming, e.g., rising surface temperatures, rising sea levels and other negative ecosystem impacts have been slower to register with the wider community. Repeatedly over the period of this study, it has been reported by the Australian Bureau of Meteorology (BOM 2018) that sea and air temperatures have risen. The incidence of hot days and marine heatwaves has increased, and cool extremes have decreased.

Embodied in the research are the anticipated reductions in the level of greenhouse gas pollution that will, overall, be emitted from the emissions sources in each of the case studies. This assumed reduction in emissions is well supported by the evidence.

This situation shows a moderate correlation with the outcomes of the US ARP, even though the US ARP was positively impacted by a narrow sectoral coverage, available emission reduction technologies and the ability to switch to lower sulphur content coal. In addition, the US states most affected by the ARP related job losses were supported by compensation and some retraining of redundant employees.

The data collected in the preceding Chapters 2 and 3, and further developed in Chapter 4 is now used in the greenhouse gas case study in Chapters 5 and 6 that follow. Chapter 5 on the EU ETS and Chapter 6 on the RGGI both utilise a framework of constraints and design factors that have been established up to this point of the study. The aim is to apply uniform metrics across both case studies, although there is some variation in the way data is collected and presented in each of the case study chapters.

Chapter 5: Case study on the EU ETS

5.1 Introduction

The design of the EU ETS aimed to align with the aspirations of the UNFCCC. The EU ETS was attractive as a case study primarily because of the established administrative framework of the EC. The EU ETS, from its inception was large, as it brought together, in a burden sharing arrangement, most EU member states. However, in observing the operation of the EU ETS it became apparent that success in reducing emissions was complicated by the interaction of so many participants.

Initially, the EU ETS covered 25 EU member states (Europa 2012). Data for the first compliance period for the EU ETS was released in May 2006. At the time, the first compliance period data was released, however, not all EU member states had active emission allowance registries. The 21 EU member states that had active allowance registries were issued with 1,829.5 million allowances to cover the first trading period of 2005 to 2007. Allowances in the EU ETS represent one metric tonne (t) of CO_2 or CO_2-e (1t CO_2-eq).

To encourage participation, it was determined that there would be a free initial allocation of allowances. This allocation method was based on the principle of grandfathering. The application of this principle determines an appropriate allocation of allowances based on the past levels of emission from a facility. Ellerman and Buchner (2007) observed a reputation-damaging trend in the EU ETS, as a surplus developed from a tendency toward over allocation. The first two phases of the EU ETS were characterised by little or no auctioning of allowances. The third phase from 2013 to 2020 has introduced auctioning for almost half of the allowances.

The early aims of the EU ETS were linked to the targets set in the Kyoto Protocol, and the UNFCCC acted as a parallel registry for certified emissions, as well as providing guidelines in the Protocol. As a result of this early link, both had an oversight of the greenhouse gas emissions of the liable entities in the EU ETS.

The EU ETS is governed by the EC using directives that are issued to participating EU members. These directives relate to, among other things, the targets for emissions reductions and the processes for the initial allocation of allowances.

The participating nations then develop plans to implement these directives. These preliminary plans must then be ratified by the EC. Compliance is reported to the EC and tabled in compliance data spreadsheets through CITL (later the EUTL). The latest emissions reduction commitments were submitted in 2015 to the UNFCCC in the form of an INDC at COP 21 held in Paris.

5.2 EU ETS total emissions

The information to follow shows, in summary form, the data collected from the EU ETS CITL (EUTL). An indication is given as to the trends of the year-by-year total emissions covered by the program and the change between 2005 and 2011. The year-by-year change in emissions and absolute change year by year in metric tonnes is also shown in the tables below. A negative value is attributed to a rise in emissions, as is shown to have occurred between 2005/2006, 2006/2007 and 2009/2010.

For the study period, Table 26 below shows that the change in total emissions in the EU ETS was calculated to be an overall reduction of 10.9%.

Table 26: EU ETS total cumulative percentage reduction

2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
2008780723	2030222439	2050379813	1992445310	1773888299	1833300310
(-)2030222439	(-)2050379813	(-)1992445310	(-)1773888299	(-)1833300310	(-)1787911369
Change in emissions (mmt)					
05/06	06/07	07/08	08/09	09/10	10/11
-21441716	-20157374	57934503	218557011	-59412011	45388941
Percentage change in emissions %					
-1.067	-0.993	2.826	10.969	-3.349	2.476

Table 27: EU ETS total emissions, 2005-2011, EU ETS CITL (now the EUTL)

Year	EU ETS Total emissions in million metric tonne (mmt)
2005	2008780723
2006	2030222439
2007	2050379813
2008	1992445310
2009	1773888299
2010	1833300310
2011	1787911369
	Emission reduction
2005 emissions minus 2011	220869354
Percentage reduction in EU ETS emissions	10.9%

The graphical representation shown below in Figure: 3 exhibits the curve of EU ETS emissions into the GFC period.

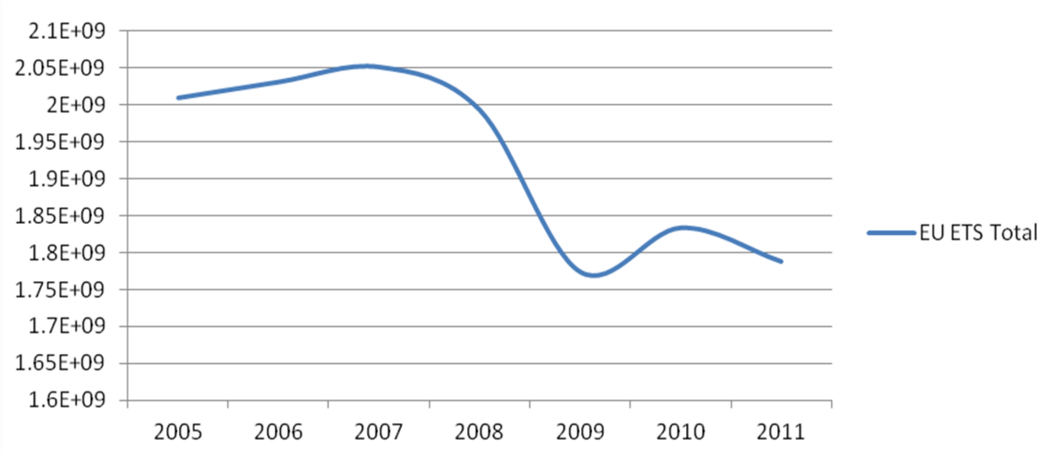

Figure 3: EU ETS total emissions, 2005-2011, EU ETS CITL (EUTL).

Source: Eurostat (2013).

In Table 28 below, the EU28 GDP growth can be seen to recover as emissions continue to fall.

Table 28: EU ETS Total GHG emissions (mmt)

Year	2011	2012	2013	2014	2015	2016	2017	2018
Verified total emissions	1904	1867	1908	1814	1803	1750	1755	1682
Change to year x-1	-1,8%	-2%	2.2%	-4,9%	-0,6%	-2,9%	0,2%	-4,1%
Real GDP growth rate EU28	1,8%	-0,4%	0,3%	1,8%	2,3%	2,0%	2,5%	2,0%

Source: EC.

5.3 Number of EU ETS participants in the study by country

In Figure 4 below, there is an indication of the number of participants in country-by-country comparison.

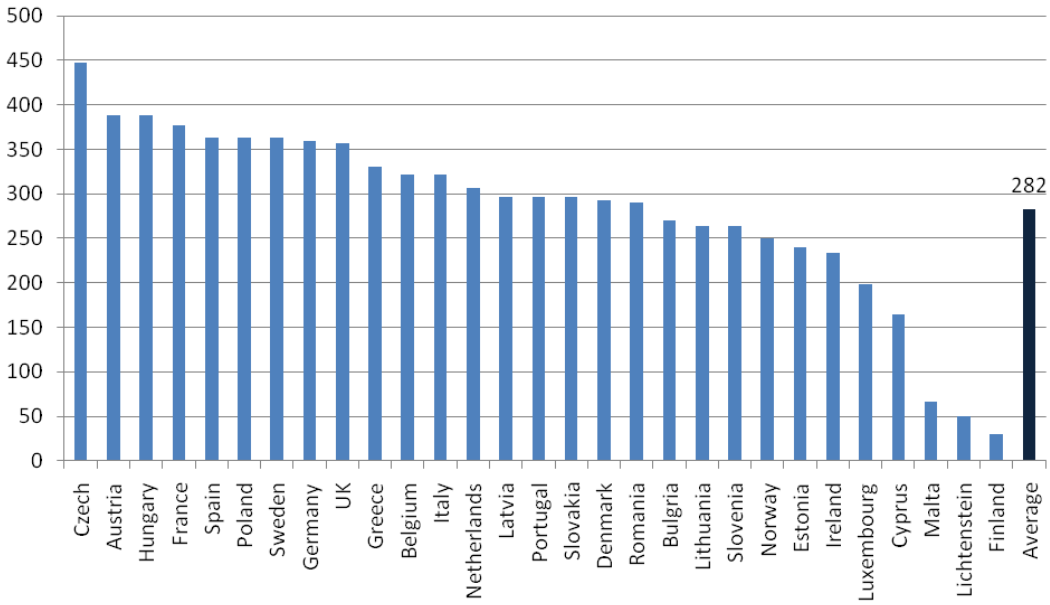

Figure 4: EU ETS participant numbers by country

5.4 The emissions of individual EU ETS countries, 2005-2011

Figure 5 below, presents the change in emissions at a country-by-country level. The absolute value in metric tonnes is derived for a country by subtracting the 2005 emissions for that country from its 2011 emissions. The results indicate that emissions reductions occurred in all groups. In absolute terms, the smallest reduction in emissions occurred in Poland and, conversely, the largest absolute emission reduction occurred in Spain.

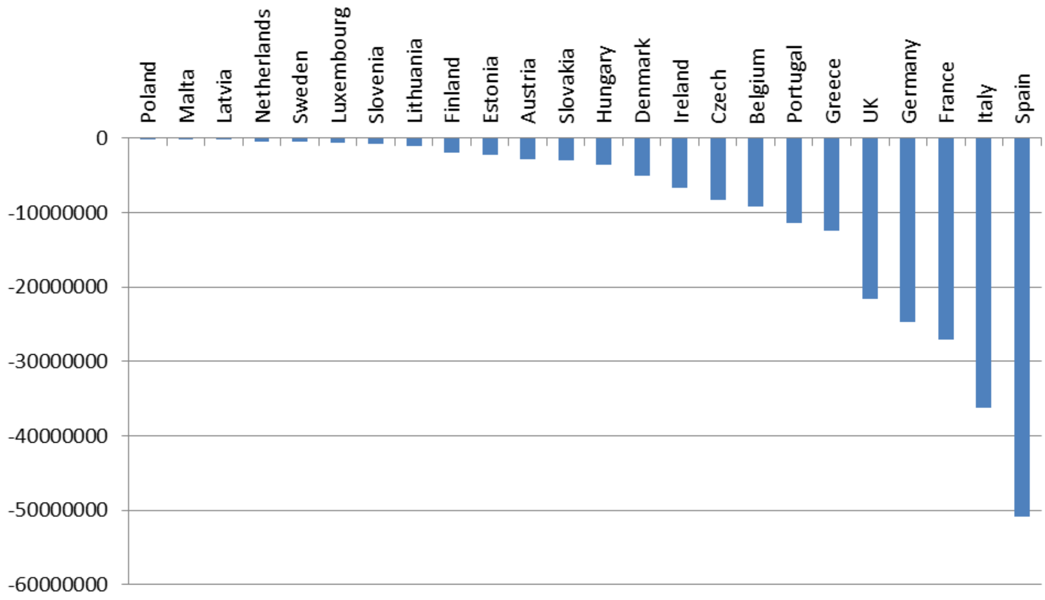

Figure 5: EU ETS countries emission reductions 2005-2011 (t)

A further comparison in Figure 6 below provides an indication of the relative percentage change in emissions, again on a country-by-country manner. This method indicates that Portugal had the largest percentage change of total emissions (31%), next was Ireland (30%) and Spain had the third largest percentage change in total emissions (28%). The large variation in the country by country percentage emissions reductions needs further explanation, although this study concentrates on the EU ETS design factors and does not pursue these differences.

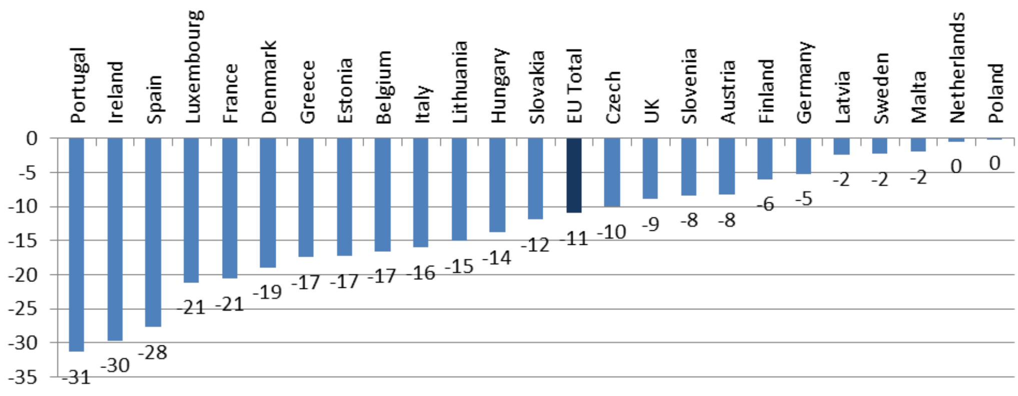

Figure 6: EU ETS countries % emission change 2005-2011

5.5 Design factors in the EU ETS

In the following section, the case study describes how the nine design factors, found in the literature, are relevant to the EU ETS. The study also then addresses the alignment of the design factors to the three constraints of acceptance, effectiveness, and emissions reduction.

An example of how the factors align with the constraints can be shown in terms of the constraint of acceptance of the EU ETS, in relation to the constraints of effective operation and emissions reduction within an ETS. The study uses the CITL (now the EUTL) as the primary reconciliation tool to provide evidence of compliance. Other obstacles, such as an excess of allowances emerged in the early stages of an EU ETS.

For example, national allocation plans were established in the EU ETS as a vehicle to administer the allocation of allowances. Laing et al. (2013) have suggested that the over allocation of allowances that resulted led to low allowance prices and in some cases windfall profits to power companies.

5.5.1 The fundamental design factors

The literature review unearthed the terms that are used to describe the design factors identified as fundamental in a framework for the implementation of greenhouse gas emissions trading. The design factors are legislation, governance, rules, compliance, and the treatment of allowances, targets, compensation, coverage, and a phased introduction.

In the EU ETS, it was found that some factors were more directly associated with the effective operation of the scheme, while another group of factors were more directly associated with the emissions reduction capability and the acceptance of the scheme. The factors of acceptance can be inversely related to emission reductions.

In the discussion that follows, these factors are viewed in a framework for the implementation of greenhouse gas emissions trading to examine the role that they play in the EU ETS.

Factor 1: Legislation

A series of rather convoluted but clear directives form the legislative process of the European Parliament regarding emissions trading. Directive 2009/29/EC came into force 20 days after the publication of the official Journal of the European Union on 5th June 2009. The aim of the directive was to "improve and extend the GHG emission allowance trading scheme of the community". It followed several earlier communications from the European Parliament, including 2003/87/EC, which established "a scheme for GHG emission allowance trading within the community and the amending council directive 96/61/EC". This directive was borne from another, 96/61/EC, which was concerned with "integrated pollution prevention and control" (European Parliament 2016).

These directives map out the progress, through the European Parliament, of policies for the abatement of greenhouse gas emissions. The cornerstones of phases one and two of the EU ETS were directives 2003/87/EC and 2009/29/EC. Transitional provisions were applied in two directives detailed in directive 2004/101/EC, which amended directive 2003/87/EC in relation to "the Kyoto Protocol's project mechanisms" and directive 2008/101/EC, which supported a strategy "for reducing the climate impact of aviation" (European Parliament 2016).

These directives are fundamental to the goal of reducing emissions as they define the scope and verification methodologies of the program. The EU member states are then obligated to develop their own NAPs to meet the commitments of the community.

Factor 2: Governance

The governance of the EU ETS has grown progressively more cohesive and coordinated. In the past, some of the challenges faced by the EC ranged from the validation of the NAPs submitted by each member state, rules to cover the retirement of a facility, new entrant provisions, the inclusion of new sectors (e.g., aviation), and protecting information from computer viruses. At the time of writing, the Directorate-General for Climate Action (DG CLIMA) was the body designated to implement and develop the EU ETS. The mission statement of the DG CLIMA declares that it will formulate climate strategy and policy, take a lead role in international negotiations, monitor national emissions, and foster the adoption of low carbon technologies (DG CLIMA 2015).

Factor 3: Rules

Over a period, both general guidelines and more binding rules have been established in the EU ETS by the EC for the monitoring, reporting and verification of greenhouse gases. In a pilot program of considerable complexity, such as the EU ETS, the detail within the NAPs has been a result of collaboration rather than the strict application of rules. The approach of the EU reflects a methodology that allows for the individual position of a country to be considered, although in the end, judgments must be made by the EC.

For this research, a distinction is made between these guidelines and rules. The guidelines were applied for the sake of clarity and distinction (e.g., what is meant by the methodology for monitoring of emissions? The EC outlined several methodologies in the guidelines for types of installations. The rules, on the other hand, related to operational requirements (e.g., can a facility change monitoring methodologies?).

Factor 4: Compliance

As already indicated, in this study, extensive use has been made of the CITL (EUTL) to assess the performance of the EU ETS. An indication as to some of the issues around providing this type data in the public domain became apparent when access to the CITL (EUTL) was blocked on 15 December 2010. This was because a Trojan computer virus warning had been issued on all registry websites. Some access conditions were applied as a result, although this virus issue was later resolved and had little impact on this study.

Factor 5: Compensation

A company that is required to surrender EUAs in the EU ETS needs to apply through the national administrator for an account in the EU's registry. In some general sense, participants are required to reduce their emissions to the required target level. In the event of the level for emissions reduction being met, allowances are required for the total emissions. If a participant can further reduce emissions below the target, excess allowances become available. These allowances can be sold or held over for the following year. If a participant's emissions targets are exceeded, then additional allowances must be found and a fine paid.

All airlines operating within the EU were liable for their greenhouse gas emissions from 2013. This extension to the EU ETS was legislated in directive 2009/29/EC of the European Parliament and of the council of 23 April 2009, amending directive 2003/87/EC to improve and extend the greenhouse gas emission allowance trading scheme of the community (Europa 2012). This directive identifies, among other things, the entities that are liable for their greenhouse gas emissions. It also details the emission reduction targets for the various EU countries.

Participants in the EU ETS have in the past been expected to account for new entrants, expansions to existing installations, and retiring plant, through the NAP allowance allocation process. In practice, an oversupply of allowances has developed since 2009 with an outcome of back loading, in which the number of allowances is temporarily restricted to reduce supply.

Factor 6: Allowances

A broad definition of allowances is taken to include their allocation, price discovery, treatment of surplus allowances and allowances as a financial asset.

Inherent in the allocation of allowances in the EU ETS is the cap. The cap refers to the total number of allowances that will be issued to cover emissions from the participating sectors. During phase two of the EU ETS, the EC policy shifted away from the NAP allocation process to a central repository for allowances. When the third trading stage commenced in 2013, decisions about allocation of allowances were reviewed at the EU level.

The EC is moving away from the NAPs that were the cornerstone of the first and second trading periods. Changes serve to demonstrate the dynamic nature of the policy decisions on greenhouse gas emissions trading. Another shift in sentiment, albeit an anticipated one, is the dropping of free or grandfathered permits. In the early years of the EU ETS, it became apparent that the grandfathering of allowances based on historical levels of emissions was resulting in many surplus permits. This flooding of the carbon market with surplus EUAs was having a debilitating effect on the health of the EU ETS. The EC has prepared a timetable to allow auctioning of all emissions allowances. The decision to auction further allowances will be supported by an appropriate EU ETS directive detailing the timing of emission allowance auctions.

The Europa website provides information from the European Commission which states:

> The EU ETS has a growing surplus of allowances built up over the last few years. It is not wise to deliberately continue to flood a market that is already oversupplied. Therefore, the Commission today has paved the way for changing the timing of when allowances are auctioned.
>
> This short-term measure will improve the functioning of the market. In phase three of the EU ETS – running from 2013 to 2020 – a large amount of allowances will be auctioned, with the revenues accruing to Member States. Macroeconomic developments in recent years give reason to consider another amendment of this time profile by postponing or 'back-loading' some auction volume from 2013-2015 towards the end of phase 3. (Europa 2008, press release)

Figure 7 below reflects a turbulent period during 2007 when oversupply of allowances meant that prices had fallen to practically zero. By 2011, the price had recovered to settle at €18. Again in 2012, the effects of an over-supplied market were felt as allowance prices reached a low of €6.5 (CDC 2012). In early 2013, EU ETS allowance prices set a record low of €2.81, this followed an EC failure to pass a vote on back loading of allowances to reduce supply.

At the time of writing, the EU member states had, after several years of debate, managed to reach agreement on restricting the supply of allowances through back loading.

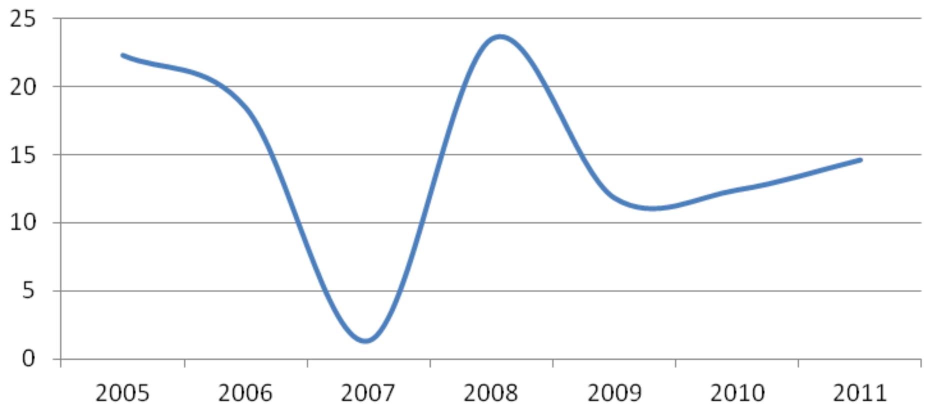

Figure 7: EU ETS allowance price discovery 2005-2011

Source: Adapted from Benz & Henglebrock 2008 and Chemical and Engineering at News http://cen.acs.org

Figure 7 above shows the early swings in the price of allowances that occurred over Phase 1 and parts of Phase 2. These variations in the allowance price have been attributed to excess allocation which was amplified by the impact of the GFC.

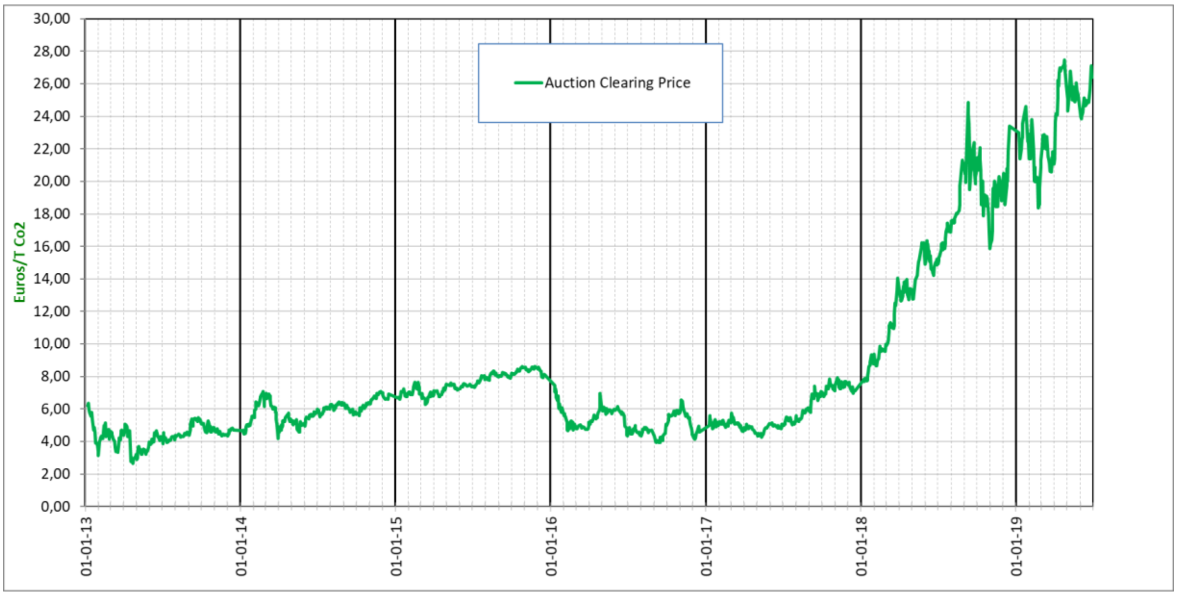

Figure 8: EU ETS Auction clearing price 2013-2019

Source: European Energy Exchange.

Figure 8 shown above indicates that after a period of instability the carbon price signal has strengthened. The EU ETS have concentrated on managing the surplus of allowances in circulation. In Phase 4, allowances will be permanently removed from the reserve on an annual basis.

The EC have indicated that the auctioning of allowances has emerged as a factor to address the impact of low prices. The inclusion of aviation has also had influence on decisions by the EC toward auctioning of allowances. In broad terms, the price trends in the EU ETS market for allowances began strongly in 2005 with a high price of around €24. The prices remained high through to 2007 at €20, at the time of writing allowances were at €25.15.

Participants in the EU ETS are obligated to reconcile their emissions with the appropriate number of allowances. The value of these new financial commodities, carbon emission allowances, is required by EC company law to be listed in the firms' balance sheets. The relevant legal perspective is codified in the fourth council directive of 25 July 1978 (78/660/EEC), based on Article 54 (3) (g) of the treaty on the annual accounts of certain types of companies.

The introduction of the allowances used in greenhouse gas emissions trading creates a new financial instrument. Entities that are participating in the market for European allowances (EAs) can be holding an asset (an EA), or be subject to a liability for the emission of a covered greenhouse gas. A report produced by accounting firm Deloitte (Concessi et al. 2007) identified the relevant EC directives that would apply to the reporting by liable entities under the EU ETS. In terms of financial accounting, they considered the relevant EC directives to be the seventh council directive 83/349/EEC of 13 June 1983, based on the Article 54 (3) (g) of the treaty on consolidated accounts.

The relevant wording in Article 16.1 states that regarding the preparation of consolidated accounts:

1. Consolidated accounts shall comprise the consolidated balance sheet, the consolidated profit and loss account and the notes on the accounts. These documents shall constitute a composite whole.

2. Consolidated accounts shall be drawn up clearly and in accordance with this directive.

> 3. Consolidated accounts shall give a true and fair view of the assets, liabilities, financial position and profit or loss of the undertakings included therein taken as a whole. (Europa 2012)

Factor 7: Targets

In the terminology used in the Kyoto Protocol, targets refer to an emission reduction target or cap. In the context of the EU ETS, these emission reduction targets are viewed as the cap on each country's total emissions, i.e., the upper limit on emissions (Europa 2015).

> The cap corresponds with the number of allowances that are put in circulation over a trading period. In Phase 3 a common EU wide cap applies, replacing the previous system of national caps. This cap decreases each year by a linear reduction factor of 1.74%, thus ensuring that the number of allowances that can be used by the stationary installations will be lower in 2020 than in 2005. (European Commission 2020).

Factor 8: Coverage

The initial coverage of the EU ETS included electric power, oil refineries, coke ovens, metal ore and steel, cement kilns, glass, ceramics, paper, and pulp (Strachan 2005). CO_2 is the main greenhouse gas covered by the EU ETS. Robinson et al. (2007) suggested that the monitoring of other greenhouse gases has not been developed to a reliable level. The EU ETS covered the greenhouse gas emissions of light duty vehicles with a target of 120g of CO_2 per kilometre by 2012. By Phase 3 which began in 2013, the EU ETS coverage had expanded to include aluminium, petrochemicals, ammonia, nitric, adipic, glyoxal and glyoxylic acid production.

Two challenges were set for the EU ETS in Phase 3: firstly, the inclusion of aviation sources; secondly, working with international partners. The aviation goal was achieved for with flights within the European Economic Area between 2013 and 2016. The EC support International Civil Aviation Organisation (ICAO) in the development of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Participants in the EU ETS have been able to use international credits related to the Kyoto instruments of the Clean Development Mechanism (CDM) and Joint Implementation (JI). The CDM and JI have generated certified emission reductions or emission reduction units which in Phase 3 have been exchanged for allowances. The EC (2020) reported that at end of 2019 the total number of international credits used or exchanged amounted to 1.51 billion or 90% of the allowed maximum. As the EU ETS moves to Phase 4 international credits will no longer be used for compliance.

Factor 9: Phasing in

The EU member states have been progressively building on a framework to achieve the greenhouse gas emissions reductions that were set in the Kyoto Accord of 2005. Phase one commenced on 1 January 2005 and was completed on 31 December 2007. Phase two commenced on 1 January 2008 and ran to 31 December 2012. Phase three commenced in 2013 and runs until 2020.

A phased introduction was established as an early requirement in the design stage of the EU ETS and was necessary for several important reasons. The data that emerged from the pilot phase of the EU ETS, between 2005 and 2007 has been used to establish an analytical framework for use in this study. The data collection followed an inductive, step-by-step path that may have mirrored some aspects of the EU ETS itself, described as a 'learning by doing' process.

It allowed for a relatively soft start in terms of the unknown outcomes. The plans for phase one, phase two and phase three could be changed to suit the current circumstances, and phase three has seen an expansion to cover aviation.

The second compliance or trading period of the EU ETS was between 2008 and 2012. This second period coincided with the first commitment period of the Kyoto protocol and the EU emissions cap was lowered by 6.5% compared to the 2005 cap (Emissions-EU ETS.com 2019).

During the third compliance period 2013 to 2020, Latvia submitted an INDC on behalf of the EU that represented a 40% reduction in greenhouse gas emissions from 1990 levels by 2030.

Other countries to submit INDCs included Australia, with a 20-28% reduction target on 2005 levels by 2030. While China's ambitious commitment was 40-45% of 2005 levels by 2020, the US 20-28% of 2005 levels by 2025, and Canada and New Zealand both committed 30% reductions on 2005 levels by 2030 (UNFCCC 2015b).

In the past, there has been a parallel application of UN protocols and EC directives to help achieve acceptance of the market-based approach. A burden sharing decision distributed an obligation to reach targets such as the 20/20/20 target – a 20% reduction of greenhouse gas emissions, with a 20% reliance on renewable energy and a 20% increase in energy efficiency measures by 2020.

External factor: Alternate policy

The EU supplements directives related to the EU ETS with several polices and activities that be parallel or alternatives to greenhouse gas emissions trading. The EU has developed linking directives in areas such as renewable energy, energy efficiency and the greenhouse gas effort sharing decision. Over time, the focus has also moved on to CO_2 standards in transport, adaptation to climate change and working with international partners (European Commission 2016b).

5.6 Design factor alignment with the constraints

This study has provided an exploration of several variable factors that are fundamental to the implementation of greenhouse gas emissions trading. These factors can be strongly or weakly aligned with the operation of the programs at the various stages of their implementation. The relative strength of alignment of a design factor may vary on the one hand to acceptance and on the other hand effectiveness. Effectiveness relates to an ETS performing adequately, but as the study has found, not necessarily achieving the desired emissions reductions.

A design factors alignment with the constraint of acceptance could reflect the level of stakeholder engagement with the processes. The constraint of acceptance acknowledges the economic burden placed on communities covered by an ETS and industry that are inextricably linked to energy from fossil fuels. Concerns about the impact of emissions trading on an economy are important in terms of compensation that is offered, emission reduction targets, how the initial allowances are allocated and scheme coverage.

A design factors alignment with the effectiveness of a scheme indicates that the factor is related to normal or legislated behaviours of the liable entities in areas such as monitoring, reporting, compliance, and administration of allowance accounts.

Design factors aligned with emissions reduction within the program are legislation, rules, coverage (wide) and participant compliance. A factor, e.g., coverage, can be found to be aligned with more than one of the constraints of acceptance, effectiveness and emissions reduction. This situation comes about because coverage may be wide as was the case with EU ETS. This wide coverage facilitates acceptance by sharing the burden between many participants. Wide coverage also, theoretically at least, lowers the cost of compliance which is the strength of a market-based mechanism (Bayer & Aklin, 2020).

From the observations made in the study this thought process led a set of questions that were developed for use in Chapter 3. The set of questions that were developed and used to rank each factor in relation to an alignment with the constraints are:

1. Did the factor appear in the original design of the program?
2. Is there a specific rule or set of rules that apply to the factor?
3. During the study has the impact of the factor grown in prominence?
4. Across the study does a factor's association with the constraints of acceptance, effective operation, and emission reductions correlate?

Table 29: Factor weighting table for the EU ETS (1)

Factor	Legislation	Rules	Governance	Coverage (wide)	Compensation	Phasing in	Targets
Weight for criteria 1	2	2	2	2	2	2	1
Weight for criteria 2	2	1	1	1	1	1	0
Weight for criteria 3	1	1	0	2	1	1	1
Weight for criteria 4	2	2	2	0	0	0	0
Totals	7	6	5	5	4	4	2

Table 30: Factor weighting table for the EU ETS (2)

Factor	Allowance allocation	Compliance
Weight for criteria 1	1	1
Weight for criteria 2	1	0
Weight for criteria 3	2	1
Weight for criteria 4	0	1
Totals	4	3

The averaging of total values for the factor weightings shown above in Tables **28** and **29 reveals that the benchmark value to determine an important factor in the EU ETS was rounded to, 5.**

The EU ETS was seen initially by the EC as a pilot program to get experience greenhouse gas emissions trading. Legislation and governance were seen to have a strong alignment with the effective operation of the EU ETS. This is in part due to the presence of the EC and its use of the established methods for developing novel programs. The directives issued by the EC in relation to the EU ETS have been the building blocks of the program. It is acknowledged that phase one of the EU ETS and, to a lesser degree, phase two have been important for the 'learning by doing' of the EU.

The view taken about compliance in phase two of the EU ETS was that economic penalties became increasingly stringent. The penalty for non-compliance in Phase 2 was €40 per tonne, in Phase 3 that figure grew to €100 per tonne (European Commission, 2020). Compliance was higher in Phase 2 than in the previous phase, as the lessons of phase one emerged.

It could be said that in the initial oversight of phase one of the EU ETS, the EC did not have a strong focus on alternative policies. There were links in the EU ETS to the complementary Kyoto Protocol mechanisms (i.e., the CDM and JI), although a primary objective for the EC when establishing the EU ETS was a focus on large CO_2 emitters. Over time, EU policies on climate change mitigation activities recognised some complementary measures, such as the effort sharing decision that includes renewables and energy efficiencies. Some participating regions also pursue greenhouse gas emissions reductions through a parallel carbon tax or similar.

Rules and targets for the EU ETS have been changing as the program developed and unusual situations, such as the Trojan virus attacks in November 2010, emerged. Targets for the EU ETS are set in two ways: on a country-by-country basis; and through 'burden sharing' arrangements that can be tailored to meet the specific needs of regions. Initially, the targets were modest when considered in relation to the long terms challenge to reduce the impacts of climate change. This cautious approach to design was evident in most early programs to avoid sudden negative economic impacts.

The allocation of permits in the EU ETS has changed after over-supply occurred in phase one. Following the first two phases of the EU ETS, the treatment of allowances was gradually modified. In the subsequent phases of the EU ETS, the rules for the allocation and banking of allowances changed to facilitate more auctioning of allowances. The introduction of interphase banking allows participating firms to hold allowances over from earlier phases. The past and planned phases of the EU ETS are "phase i 2005–2007, phase ii 2008–2012, phase iii 2013–2020, and phase IV 2021–2028)" (Balietti 2016, p. 1).

The coverage of the EU ETS is strongly aligned all three of the constraints of effectiveness, emissions reduction and the acceptance of emissions trading. The flexible characteristics exhibited by the factor of coverage allow a range of responses to the external forces that shape emissions trading. These external forces reflect the wide-ranging negotiations between countries and industrial sectors.

Expanded coverage is becoming more prominent as the third phase of the EU ETS now includes aviation. In the determination of the coverage of a program, policy needs to address the balance between reducing emissions and compensating affected parties.

5.7 Chapter summary

The study classifies a group of factors aligned to the constraints of acceptance, effectiveness and emissions reduction in the EU ETS. As the European carbon market has progressed through several developmental stages, the prominence of some factors has become more obvious.

The coverage of the EU ETS has grown and the level of emissions reductions is exceeding the 20% reduction target for 2020. Greenhouse gas emissions trading in the EU ETS aligned with several alternative mitigation strategies. A positive in terms of emissions reduction is the inclusion in the EU ETS of aviation. In the early stages, a significant negative was the oversupply and low value of allowances. Allowance prices have returned to stronger prices after the adoption of an allowance stability reserve. This pool of allowances was removed from the market to manage the excess of allowances and the low prices.

The EC considers that the various phases of the overall program allow for a full debate on the development of changes to the EU ETS framework. The inherent flexibility of cap and trade has been important, as the rules for the operation of the EU ETS have been the subject of several amendments and new directives from the EC. Amendments to the directives underpin this flexibility, although they may introduce some uncertainty about the process and its outcomes for business. The phased introduction of the EU ETS was important for acceptance, although it has meant that progress may have been slow toward reducing emissions.

From the experience with the GFC and now the COVID 19 pandemic, the effect of introducing a dip in emissions generally across the EU there may be an opportunity to introduce stronger targets for reducing emissions. Some observations about the emission reducing effect of the GFC and COVID 19 and the emissions rebound (Wang & Wang, 2020) are made in the comparative Chapter 7.

In the case study Chapter 6 to follow, the RGGI is assessed in a similar fashion. In the RGGI, the factor comparison is informed by the preceding study of the EU ETS.

Chapter 6: Case study on the US RGGI

6.1 Introduction

The same approach that was used in the case study on the EU ETS is now used on the second case study, the RGGI, to observe aspects associated with the three constraints and nine design factors. The two case studies are considered to be comparable in a conceptual sense as they use a quantity-based market mechanism to produce a price signal that seeks to abate emissions of the greenhouse gases. Given that the RGGI is focussed on just the stationary energy sector of nine US states, the studies are not as similar from a contextual perspective.

In the previous case study, mention was made of the emissions reducing effect of the GFC. Subsequent research has established that in the EU ETS the price of allowances fell over the GFC period (Murray & Maniloff, 2015; Schmalensee & Stavins, 2015; Haites et al. 2018, Bayer & Aklin, 2020). In this chapter, curves are developed for the case study on the RGGI using GDP and greenhouse gas emissions to consider if the RGGI suffered from the same distortion while coming out of the GFC period.

The structure of the RGGI Inc. is examined to determine if it facilitates the effective operation of the program. Unlike the activities in the EU ETS, the aims of the RGGI program were not as closely aligned to the caps in the Kyoto Protocol. The stated aims of the RGGI board were:

> Development and maintenance of a system to report data from emissions sources subject to RGGI, and to track CO_2 allowances. Implementation of a platform to auction CO_2 allowances and monitoring the market related to the auction and trading of CO_2 allowances. Providing technical assistance to the participating states in reviewing applications for emissions offset projects. Providing technical assistance to the participating states to evaluate proposed changes to the States' RGGI programs. (RGGI 2012)

The aims, as stated above, provided criteria that have been used to establish the degree to which the RGGI program can be assessed a success or otherwise. The first point relates to the factors that were among the building blocks of a framework for the design of a greenhouse gas emissions trading program. These were the reporting of verified emissions and the development of a market in CO_2 allowances.

At the time of writing, greenhouse gas emissions trading has not been introduced at the federal level in the US, although regional support has seen the emergence of programs such as the RGGI and the Californian Cap and Trade Program (CCTP).

6.2 RGGI total emissions

To determine if there had been regulatory compliance in the RGGI, an analysis of the data from the COATS was undertaken. The COATS data indicated that, overall, there had been a high level of compliance by participants in the RGGI.

The next step in the research process was to establish the overall outcomes for emissions from the RGGI in the first control period (2009 to 2011). A detailed state-by-state analysis of reports in the COATS database was carried out for this purpose. The results were taken from a three-year data set and may be considered a narrow range in terms of the multi-generational aspirations that are a necessary part of programs for greenhouse gas emissions trading.

The state-by-state data obtained from the RGGI COATS database is shown below. The reported units of CO_2 emissions are shown in short tons.

Table 31: RGGI COATS state-by-state emissions data (1)

	Connecticut	Delaware	Maine	Maryland	Massachusetts
31-12-09	7,322,363.83	3,708,331.13	3,643,492.68	26,568,682.67	18,661,075.54
31-12-10	8,527,102.23	4,299,269.49	3,943,457.44	28,909,657.68	19,804,383.76
31-12-11	7,018,498.12	4,150,396.00	3,337,459.90	26,631,106.15	15,634,871.54

Table 32: RGGI COATS state-by-state emissions data (2)

	New Hampshire	New Jersey	New York	Rhode Island	Vermont
31-12-09	6,337,055.87	16,359,443.06	37,861,407.93	3,416,782.91	1,965.30
31-12-10	6,420,303.23	19,681,307.82	42,113,171.11	3,504,391.68	3,756.00
31-12-11	5,996,533.95	17,117,779.46	37,137,382.25	3,946,582.06	6,536.90

Table 33: RGGI combined emissions data for the first control period, 2009-2011

	RGGI combined emissions data for CO_2 emissions (imp' short tons)
31-12-09	123,880,600.92
31-12-10	137,206,800.44
31-12-11	120,977,146.33

When shown in a graphical format, as seen below in Figure 9, it appears that the RGGI program objective of stabilising the emissions of CO_2 had been achieved (indicated by the smoothed chart line and linear trend line). In Table 34 the combined GDP of the RGGI states is shown, over the same short period (2009-2011) to have rose steadily. A growth in GDP of US$188.5b indicates that RGGI CO_2 emissions and GDP did not correlate.

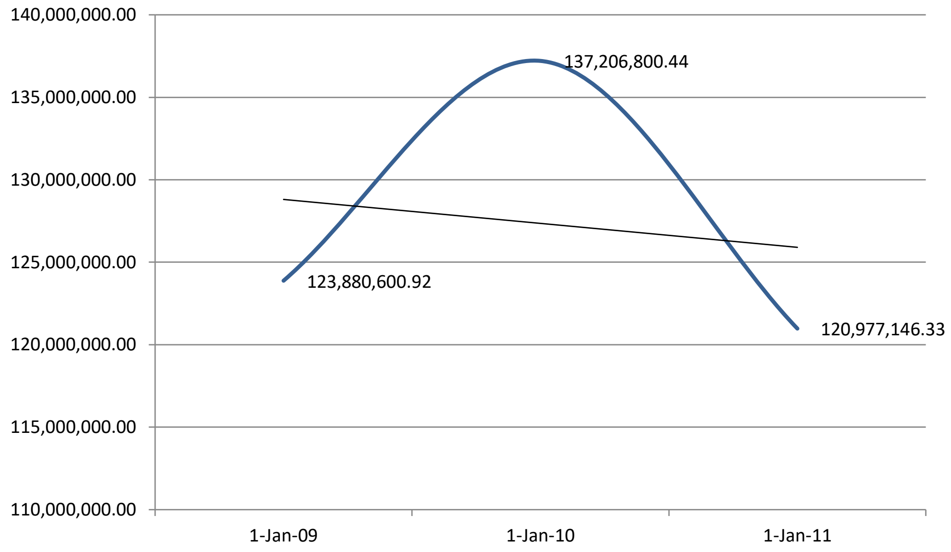

Figure 9: RGGI total emissions 1st control period 2009-2011(s/tons)

Table 34: RGGI states GDP US$b

	31/12/2009	31/12/2010	31/12/2011
Connecticut	213.5	221.3	230.1
Delaware	60.1	64.0	65.8
Maine	50.2	50.7	51.6
Maryland	283.6	293.3	301.1
Massachusetts	360.6	377.8	391.8
New Hampshire	59.0	61.6	63.6
New York	1072.3	1128.8	1158.0
Rohde Island	47.7	48.8	50.1
Vermont	24.2	25.3	25.9
New Jersey	471.5	483.0	493.2
RGGI states GDP (US$b)	2642.7	2754.6	2831.2

Source: US Dept. of Commerce (2013).

An analysis of the greenhouse gas emission trends for each of the US states participating in the RGGI indicates that five were able to achieve some reductions in the electricity sector emissions of CO_2. However, five states showed an increasing level of electricity sector emissions during the first control period (Figure 10).

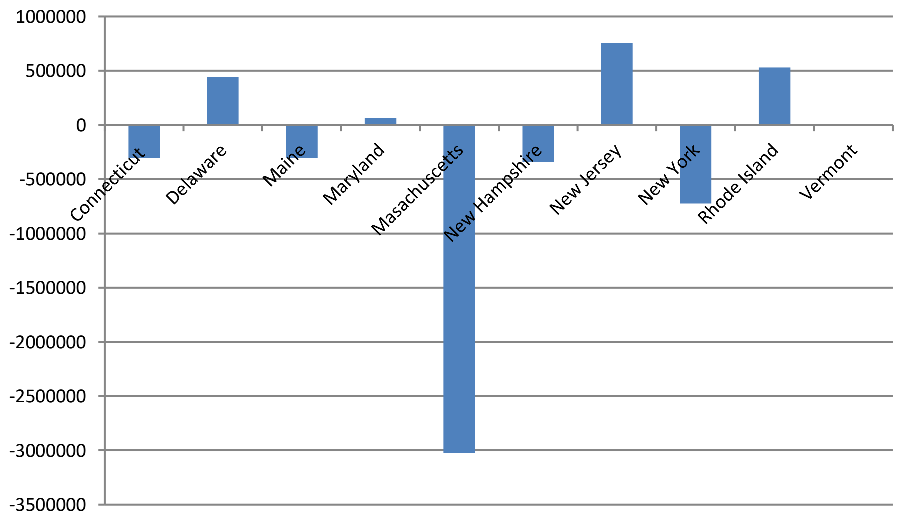

Figure 10: RGGI state comparison change 1st control period emissions, 2009-2011

The total emissions reduction achieved in the RGGI over the first control period covering 2009 to 2011 was 2,903,454.59 short tons. The total emissions in the RGGI over this period were 382,064,547.69 short tons. The percentage reduction in overall emissions for the first control period was 0.8%.

6.3 Analysing the data from the CO_2 Allowance Tracking Scheme (COATS)

The state-by-state data contained in the RGGI COATS database suggest that there had been compliance with the rules of the RGGI program. The data also indicates that the initial objectives of the RGGI program, stabilisation of CO_2 emissions by 2015, were, generally, on track. The summary data shown in Table 34 indicates that emissions reduction in the RGGI (-0.8%), exceeding the target of emissions stabilisation.

Table 35: RGGI first control period emissions target

RGGI CO_2 reduction	2,903,454.59 short tons
Percentage RGGI reduction	-0.8%

6.3.1 RGGI states in which there were emissions reductions (shown in short tons)

The first reporting period data indicates thst there was an overall reduction in greenhouse gas emissions across the RGGI, the results indicate that reductions were not found in all states. In five states, there were emissions reductions as shown in the Table 35.

Table 36: RGGI states' percentage contribution to overall emissions reductions

Connecticut	New Hampshire	Maine	New York	Massachusetts
-5.99%	-4.91%	-2.86	-30.65	-14.16

Table 37: RGGI states total contribution to overall emissions reductions

Total emission reduction
4,700,650.09 short tons CO_2

6.3.2 RGGI states in which there were emissions increases

In contrast to the section above, there were five RGGI states that were characterised by emissions increases. Table 37 shows the results for the five RGGI states that exhibited GHG emissions increases (shown in short tons) and their total contribution.

Table 38: RGGI states' percentage contribution to overall emissions increases

Delaware	Maryland	New Jersey	Rhode Island	Vermont

3.18%	21.49%	13.91%	2.84%	0.00%

Table 39: RGGI states' total contribution to overall emissions increases

Total emissions increase
1797195.50 short tons CO_2

6.4 RGGI COATS emissions data from control periods 2 and 3

Over the two control periods that followed, 2012-2014 and 2015-2017, seven RGGI states achieved overall emission reductions, leaving two states with increased emissions. New Jersey an original RGGI participant that left the program after the first control period, has returned to the RGGI in 2020 at the end of the fourth control period.

Table 40: RGGI emissions control periods 2 and 3

State	Control period 2 (tons)	Control period 3 (tons)	Change
Connecticut	21,845,515.37	22,668,441.13	+822,925.76
Delaware	13,057,571.61	10,805,352.83	-2,252,218.78
Maine	7,807,967.97	4,411,036.55	-3,396,218.42
Maryland	60,183,852.24	49,060,663.26	-11,123,188.98
Massachusetts	38,691,095.34	34,318,266.06	-4,372,829.28
New Hampshire	11,869,270.91	8,347,233.64	-3,522,037.27
New York	103,145,754.89	87,794,882.21	-15,350,872.68
Rhode Island	9,274,180.03	9,118,717.74	-155,462.29
Vermont	7,787.70	8,242.70	+455
Total emissions reduction between periods 2 & 3 (tons)			39,193,984.65

Source: RGGI COATS (2020).

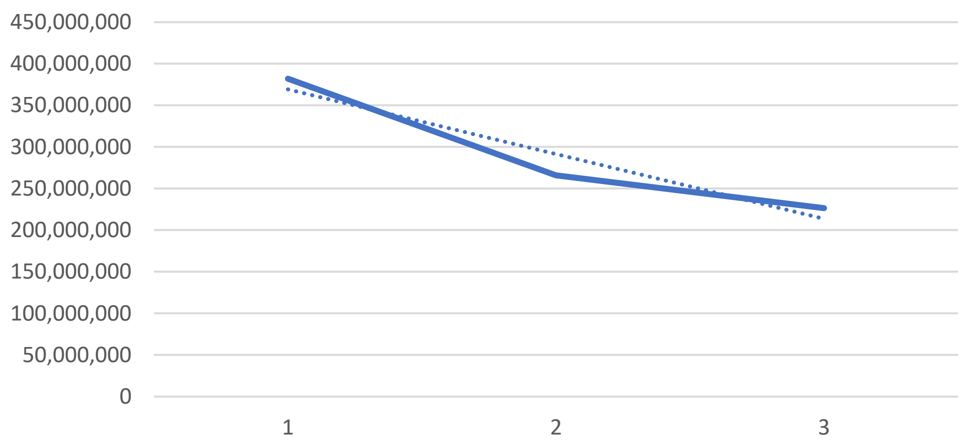

Figure 11: RGGI total emissions control periods 1, 2 and 3, short tons

Source: RGGI (2020).

The material shown above in Table 39 and Figure 11 was taken from the RGGI COATS database. It reveals that between the second control and third control periods greenhouse gas emissions have continued to fall across the program.

6.5 Factor comparison in the RGGI

As previously outlined, several variable factors were identified as being important in a framework for the implementation of greenhouse gas emissions trading. As in the previous case of the EU ETS in this chapter on the RGGI, there are indications that some factors were strongly aligned with effective operation, while others were more directly associated with emissions reduction and the acceptance of the scheme.

What follows is a description of all the factors and their impact in the RGGI. The first reporting period (2009-2011) served to develop the processes of auctioning allowances and the reporting and reconciliation of emissions. Unlike the EU ETS, the prior use of tradable permits in the US meant that the first three years of the RGGI program were less of a ‘learning by doing’ phase and more aligned with effective operation.

The factors associated with acceptance in the EU ETS were found to be somewhat less important in the RGGI. The factors related to effective operation in the RGGI program were refined relatively quickly in the early allowance auctions and reconciliation stages. In a developmental sense, the position of the RGGI has become that of a functioning carbon market. In the previous chapter on the EU ETS, it was apparent that in this program, a functioning carbon market was slower to develop.

In this study, the stages of an emissions trading program are described in Figure 1 Conceptual framework (Section 1.6). This conceptual framework for an emerging carbon market describes firstly, the original design parameters, secondly, the later distortions that occur due to external forces, and thirdly the changes that are required to the original design.

6.5.1 The fundamental design factors

Factor 1: Legislation

The RGGI model rule consists of ten sub-parts: CO_2 budget trading program general provisions; CO_2 authorised account representative for CO_2 budget sources, permits, compliance certification; CO_2 allowance allocations; CO_2 allowance tracking system; CO_2 allowance transfers, monitoring and reporting, reserved; and CO_2 emissions offset projects (RGGI 2012).

An example of how the states were guided by the RGGI model rule comes from the example of New Hampshire, where a detailed document called *The New Hampshire Code of Administrative Rules – Chapter Env-A 4600 Carbon Dioxide (CO_2) Budget Trading Program* was created. Similar, although not identical, administrative arrangements were provided for the other states. The negotiations that led to the RGGI model rule grew to include Massachusetts, Rhode Island, and Maryland.

In comparison, the EU ETS was considerably more ambitious both in scope and scale. The much larger scale of governance required by the EU ETS was likely to have caused the perceived inefficiency of that program, particularly in relation to the initial allocation of allowances.

Factor 2: Governance

In the RGGI, a new body was formed to provide governance. Governors from Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont worked as a group to design a MoU regarding a regional cap and trade ETS. As the number of participant states grew, a not for profit RGGI Inc. board was convened to oversee further implementation.

The states participating in the RGGI developed their own rules, governing the conduct of participants in the program. In the preliminary planning, some guidance was given to the states in the model rule.

In contrast to the EU ETS, the RGGI had an independent market monitor, Potomac Economics. The role of the market monitor was, in broad terms, to report on the activities and effectiveness of the RGGI allowance auctions. Potomac Economics also sought to identify potential distortions and manipulations in the market. Given their pivotal position in the RGGI, Potomac Economics could make recommendations in terms of improving the operation of the program.

Factor 3: Rules

In comparing the operating rules of the EU ETS and the RGGI, there was a significant difference in how the rules were established and later modified. In the case of the EU ETS, there was an established methodology under the EC regarding the development of the program rules or directives. The directives were then used to establish subsequent regulations or rules, such as the EC regulation (EU) No. 601/2012, related to the monitoring and reporting of greenhouse gas emissions pursuant to directive 2003/87/EC of the European Parliament and of the council. While greenhouse gas emissions trading on a wide scale in Europe was new, the supporting processes of the EC for the EU ETS followed established patterns.

This was not quite the case for the RGGI. The development of rules and regulations in the RGGI had a less established path to follow. The RGGI was a by-product of an existing coalition within the NEG-ECP. Between 2005 and 2008, the forum of the NEG-ECP developed an action plan on climate change. This action plan included a goal of reducing greenhouse gas emissions in the region. This plan served to initiate activity in the areas of energy security, sources of renewable energy and atmospheric standards.

The interrelatedness of the ecological and economic futures of the New England states and Eastern Canadian provinces had previously been discussed in terms of wetlands, agriculture, forests, and water (Molnar & Kubiszewski 2012). In the forum provided by the NEG-NCP, a climate change action plan was placed on the agenda. The Eastern Canadian provinces involved in the NEG-ECP were Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland, Labrador, and Quebec. Of these Canadian provinces, Quebec has linked with the Californian emissions trading program and the US western climate initiative (WCI) in a wider carbon market.

The RGGI CO_2 budget trading program was a US only program in that linkages to other programs were not foreseen in the first control period. The model rule upon which the RGGI is based emerged to complement the various state-based legislation. In the RGGI rules and, as with the EU ETS, guidelines exist in three main categories: the model rule; rules for the conduct of auctions; and the state-based rules to which participants must adhere.

The research in this study focussed primarily on the structure of the model rule. The model rule was linked to the US EPA Code of Federal Regulations, Title 40 (protection of environment) Parts 96 and 97(NO_X budget trading program and SO_2 trading program), and Part 98 (mandatory GHG reporting) (US EPA 2013a). In the RGGI, the model rule was developed to provide guidance and consistency to the states that signed the RGGI MOU as they implemented the program (RGGI 2007).

The eight main aspects of the model rule are listed here with a brief outline of each component:

- Applicability – determined the type of emitting installations that were required to report on emissions. In a general sense, in the RGGI reporting, installations are fossil fuel fired electric generating units with a capacity of 20MWs or greater. Further clarification was provided under the model rule as to what constitutes a fossil fuel fired unit.

- Size and structure of cap – participants in the RGGI were required to stabilise their CO_2 emissions over the first two control periods of the RGGI between 2009 and 2014, then further emissions reductions of 2.5% for each year from 2015 to 2018. These targets were not as ambitious as those in the EU ETS. The model rule acknowledged that these low targets were aimed at minimising the impact on retail electricity prices.

- Permitting – required the state regulatory authorities to have an emission monitoring plan (EMP) from each CO_2 budget source in that state. These EMP were then used to develop the state emissions budget. From the state emissions budget a regional emissions budget could be established.

- Allowance allocation – the allowances were distributed amongst CO_2 sources according to regional requirements. The allowances represented one ton of CO_2. The allowances were allocated through an auction process with the proceeds then distributed to non-specific projects and electricity consumers. The model rule included incentives for early retirement allowances (ERA), which allowed their inclusion in the next round of auctions. This provision was an attempt to avoid the free rider effect created when CO_2 emitters can easily meet the cap. In theory, as renewable energy sources penetrate the electricity markets the CO_2 cap can be more easily reached.

- Temporal flexibility mechanisms – temporal or time flexibility was provided under the model rule through provisions for banking, extending compliance and early retirement. Borrowing allowances was not permitted.

- Price triggers – although these were not binding, stage one and stage two price triggers were used in the RGGI to dampen high permit prices. A stage one trigger was set at a twelve-month rolling average CO_2 allowance price greater than US$7. A stage two trigger was set at a twelve-month rolling average CO_2 allowance price greater than US$10. If these trigger events occurred, CO_2 sources could use offset allowances to meet preset percentages of their obligation. In the event of stage one and two price trigger events, the allowed use of CO_2 offset allowances increased to 5% and 10% of a source's total annual obligation (RGGI 2007).

- Offsets – CO_2 offsets relate to allowances for projects outside the capped sector. The use of CO_2 offset allowances was restricted to 3% of a source's total annual obligation. These offset allowances were from projects outside of the US that were certified pursuant to the UNFCCC protocols.

- Emissions monitoring – the owner/operator of a CO_2 source was required to install quality assured monitoring equipment based on the US EPA monitoring provisions, 40 CFR Part 75.

Factor 4: Compliance

Within the COATS are reports that provide an array of information to the public, while others are available only to registered participants. These reports are listed below in Table 40.

Table 41: RGGI COATS reports

Report	Content
Special Approvals	Customer-side distributed resources, early reduction allowances, long-term contract allowances, useful thermal energy, voluntary renewable energy credits, unsold allowance retirement, limited industrial exemption, co-generation allowances and fixed price allowances
Offset Projects	None listed
Accounts	Account number and name, owner operator, account type (compliance or general)
Account Representatives	Account, ORIS code, authorised representative, and alternate representative and operator
Sources	Individual source name, ORIS code, state and unit I.D.
Owner/Operator	Registered account name and owner/operator
Transaction Price Report	RGGI auction distributions and allowance transfers from settlement on a futures exchange
Quarterly Emissions	Unit/Source quarterly based emissions data as reported to the US EPA
Annual Emissions	Unit/Source annually based emissions data as reported to the US EPA
Control Period Emissions	Source emissions data as reported to the US EPA
Summary Level Emissions	State emissions data as reported to the US EPA
Compliance Summary	State derived evaluations of compliance

Factor 5: Compensation

The RGGI model rule did not specify the terms of entry for new participants or the exit provisions for the retirement of a CO_2 source. The detail on compensation (exit and entry) provisions existed in the state statute and regulations section of the RGGI program design pages. The regulations for each state varied slightly as they were drawn up by different state-based departments. There was generally a requirement that a new entrant would have to apply for a CO_2 source account. This application would then have to be approved by the appropriate state body. A CO_2 source owner/operator would have to have an authorised account operator and an alternate authorised account operator. Some of the state-based statutes around entry provisions referred to the monitoring requirements as set out in the US EPA 40 CFR part 75.

As far as exit provisions go, there was usually a requirement for the authorised account operator to nominate how the allowances for a retiring CO_2 would be transferred to another account registered with the RGGI COATS system. The administrator of a state-based emission budget might also cancel an account after an appropriate period of inactivity and the absence of any allowances. By way of example, for the state of Vermont the relevant state statute and regulations for compensation (exit and entry) of the RGGI are set out below. The information was taken from the CO_2 budget trading program general provisions for Vermont:

> Subchapter II. Authorized account representative for CO_2 budget sources. 22-201 Authorization and responsibilities of the CO_2 authorized account representative. 22-202 Alternate CO_2 authorized account representative. 22-203 changing the CO_2 authorized account representative and the alternate CO_2 authorized account representative; changes in the owners and operators. 22-204 Account certificate of representation. 22-205 Objections concerning the CO_2 authorized account representative. 22-206 Delegation by CO_2 authorized account representative and alternate. CO_2 authorized account representative.
>
> Subchapter III. Permits 22-301 General CO_2 budget permit requirements. 22-302 Submission of CO_2 budget permit applications. 22-303 Information requirements for CO_2 budget permit applications.
>
> Subchapter IV. Compliance certification. 22-401 Compliance certification report. 22-402 Agency’s action on compliance certifications. Subchapter VI. CO_2 allowance tracking system. 22-601 CO_2 allowance tracking system accounts. 22-602 Establishment of accounts. 22-603 CO_2 Allowance tracking system responsibilities of CO_2 authorized account representative. 22-608 closing of general accounts.

> Subchapter VII. CO_2 allowance transfers. 22-701 Submission of CO_2 allowance transfers. (RGGI Inc. website 2013a)

Factor 6: Allowances

Four sub-categories were identified within the main factor category of allowances: the allocation of allowances; allowance price discovery; the treatment of surplus allowances; and allowances as a financial asset. The auctioning of allowances in the RGGI was monitored by a market monitor (Potomac Economics) for the whole of the first reporting period. During this period, from 2009 to 2011, fourteen auctions were held. The market monitor released a detailed report on each auction and issued a statement as to the general conduct of each auction, as follows:

> Based on our review of the administration of the market, we found that: the auction was administered in a fair and transparent manner in accordance with the noticed auction procedures and limitations. The auction results were consistent with the market rules and the bids received. Sensitive information was treated appropriately by the auction administrator. There were no indications of hardware or software problems, communications issues, security breaches, or other problems with the auction platform. (RGGI 2013b)

It was the opinion of the market monitor that all auctions carried out during the first reporting period were without concern in terms of conduct. However, an anomaly emerged in auctions three to twelve, inclusive, where allowances were available to purchase in the next (future) reporting period. In the RGGI allowances are retired after 3 years.

Price discovery

The total proceeds from all auctions in the first reporting period were US$845,653,233.70. The average clearance price was US$2.33. The highest clearance price at any auction was US$3.51(at the third auction), while the lowest clearance price at an auction was US$1.86 (at auctions nine and ten). The largest number of bidders at any auction was 84 (at the second auction); while the smallest number of bidders at an auction were 25 (at auction twelve).

Statistics for the auctions held in the first reporting period are shown below in Table 41. A linear representation of the auction results is provided below also in Figure 12.

Table 42: RGGI first reporting period auctions

Auction	Clearing price (US$)	Number of bidders	Ratio of bidders to allowances	Proceeds from auction (US$)
1. 25 Sept 2008	$3.07	82	4.1	$38,575,738.90
2. 17 Dec 2008	$3.38	84	2.5	$106,409, 935.24
3. 18 March 2009	$3.51	50	2.5	$117,248,629.80
4. 17 June 2009	$3.23	54	2.6	$104,242,445.00
5. 9 Sept 2009	$2.19	46	2.5	$66,278,239.35
6. 2 Dec 2009	$2.05	62	2.6	$61,587,120.90
7. 10 March 2010	$2.07	51	2.3	$87,956,944.56
8. 9 June 2010	$1.88	43	1.3	$80,465,566.78
9. 10 Sept 2010	$1.86	45	0.75	$66,437,340.00
10. 1 Dec 2010	$1.86	38	0.57	$48,224,220.00
11. 9 March 2011	$1.89	36	1.1	$83,425,588.47
12. 8 June 2011	$1.89	25	0.30	$25,477,200.00
13. 7 Sept 2011	$1.89	31	0.18	$14,150,430.00
14. 7 Dec 2011	$1.89	38	0.63	$51,583,770.00
Averages	$2.33	49	1.81	$65,050,248.75 (Total 845,653,233.76)

Source: RGGI (2013b).

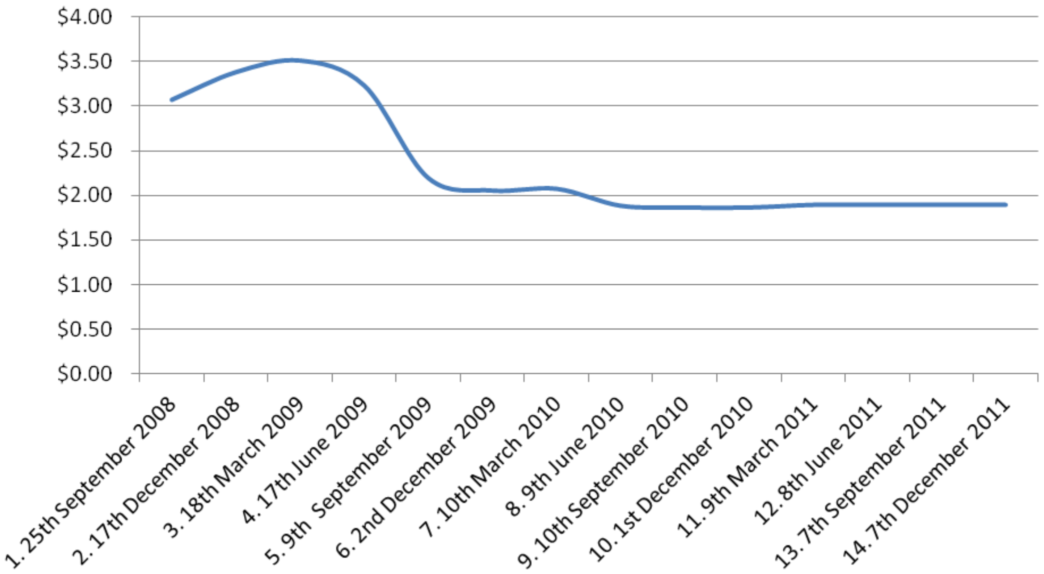

Figure 12: RGGI auction results 2008-2011 (US$)

As the RGGI program has progressed, the auction results for the next three control periods has become available. The results of these auctions are shown below in Table 42 and Figure 13. A strong price signal has emerged with the average price of an allowance between 2014-2020 being US$4.20. The average price between the first control period and the fourth control period rose by US$1.90. The price of allowances rose and fell over the last 3 control periods from a low of US$1.89 to a high of US$7.50. The level of price variation did not become binding on the upper or lower RGGI price collar.

Table 43: RGGI subsequent reporting period auctions

Auction	Date	Price (US$)	Proceeds (US$)
48	3/06/2020	5.75	$93,933,713.50
47	11/03/2020	5.65	$91,577,160.55
46	4/12/2019	5.61	$73,583,250.84
45	4/09/2019	5.2	$68,205,524.40
44	5/06/2019	5.62	$74,304,565.86
43	13/03/2019	5.27	$67,895,707.72
42	5/12/2018	5.35	$71,479,472.15
41	5/09/2018	4.5	$61,155,481.50
40	13/06/2018	4.02	$55,359,520.50
39	14/03/2018	3.79	$51,368,776.93
38	6/12/2017	3.8	$55,814,358.20
37	6/09/2017	4.35	$62,516,394.75
36	7/06/2017	2.53	$36,931,599.10
35	8/03/2017	3	$43,113,900.00
34	7/12/2016	3.55	$52,509,168.25
33	7/09/2016	4.54	$67,697,370.10
32	1/06/2016	4.53	$68,356,123.56
31	9/03/2016	5.25	$77,903,343.00
30	2/12/2015	7.5	$115,307,055.00
29	9/09/2015	6.02	$152,753,249.88
28	3/06/2015	5.5	$85,291,640.50
27	11/03/2015	5.41	$82,625,144.70
26	3/12/2014	5.21	$94,815,148.85
25	4/12/2014	4.88	$87,833,592.56
24	5/12/2014	5.02	$90,673,167.68
23	6/12/2014	4	$93,965,400.00
22	7/12/2014	3	$114,988,134.00
21	8/12/2014	2.67	$102,552,144.81
20	9/12/2014	3.21	$124,490,463.96
19	10/12/2014	2.8	$105,939,134.00
18	11/12/2014	1.93	$38,163,820.00
17	12/12/2014	1.93	$47,456,770.00

16	13/12/2014	1.93	$40,416,130.00
15	14/12/2014	1.93	$41,608,870.00
14	15/12/2014	$1.89	$51,583,770.00
Averages		$4.20	$75,547,687.62
Total proceeds			$2,644,169,066.85

Source: RGGI, 2020.

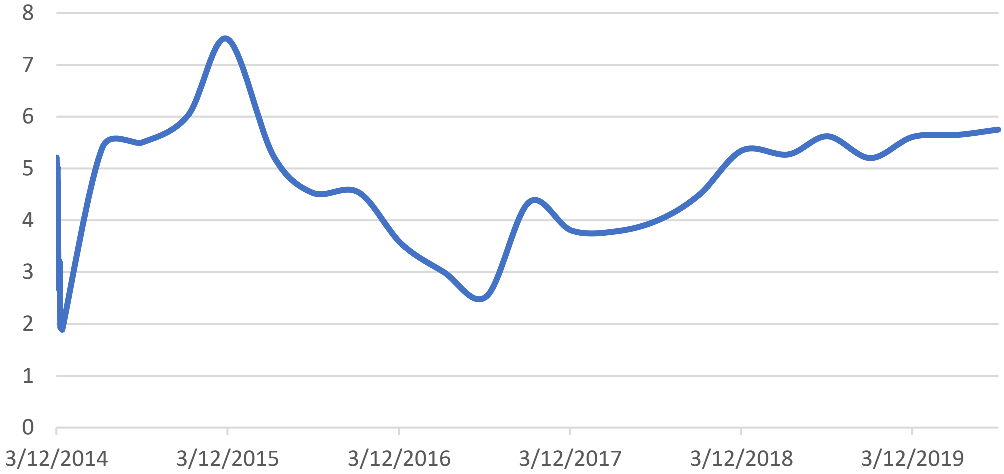

Figure 13: RGGI auction results 2014-2019 (US$)

In the RGGI, as the allowances were auctioned some surplus allowances were held in private ownership. These could be banked for later or transferred according to state statutes. Any remaining surplus allowances that were not sold at auction were held by the appropriate state, which were likely to be retired to facilitate efficient operation of the emissions trading program.

The bodies that determined the appropriate accounting treatment of intangible assets, such as emission allowances, were not able to agree on a common approach. In 2005, the accounting principles that were proposed by the International Financial Reporting Standards Interpretations Committee (IFRIC) did not gain acceptance. These principles meant that allowances were to be recorded as intangible assets. Periodic emissions expenses and related liabilities were reported based on the carrying amount of allowances needed to satisfy actual emissions.

The Generally Accepted Accounting Principles (GAAP) considered that allowances should be reported at historical cost and treated as inventory (Fornaro, Winkelman &

Goldstein 2009). In the early part of 2013, under the oversight of the IFRS, the International Accounting Standards Board (IASB) established a consultative group. This group developed a research project to gather evidence on emissions trading as a rate-regulated activity (IFRS 2013).

In the previous case study on the EU ETS, the development of three markets was discussed: the voluntary market for carbon offsets; the initial distribution of allowances in the primary market; and the secondary market, where allowances for an entity's reconciliation of emissions could be traded. Each participant in a cap and trade scheme had to surrender an allowance for each ton of a GHG that has been emitted. Experience has shown that a secondary market for these tradable allowances develops as some participants can more easily reduce their emissions.

In the RGGI program, the primary market was the auction of allowances. This had a target of stabilisation of emissions that appeared to have reduced activity on two other component markets that emerged with emissions trading. These emergent markets were the voluntary market for carbon offsets and a secondary market that supported trade between participants in any available excess allowances.

External forces may also have contributed to reduced activity in these markets for allowances under constrained economic activity. It was anticipated that these aspects of emerging market activity with emissions trading could slowly change, principally because of deepening targets for emissions reductions in the future control periods of the RGGI. It has transpired that the participants were able to meet and, in some cases, exceed the more stringent emissions reduction targets.

Factor 7: Targets

As mentioned in the discussion on the financial aspects of emission allowances, the targets in the RGGI program seem modest at first. In contrast to many tradable permit programs, the initial aim of the RGGI was to stabilise CO_2 emissions in the power sector. Between 2009 and 2014, the RGGI program sought to stabilise emissions at 188 million short tons and, in each subsequent year to 2020, reduce emissions by 2.5% (CORE 2011).

Factor 8: Coverage

The coverage of the RGGI was narrow when compared to the EU ETS, which was mandatory for several industrial sectors. Under the program, only emissions from electricity generators with a capacity of 20 MWs or greater were covered. Known as regulated units, these generators were required to hold CO_2 allowances equivalent to their emissions over the first three-year reporting period. There were various exceptions to the model rule relating to variations in the output of a generator on a seasonal basis. There were also modified rules relating to plants that used a mix of fossil and biomass fuels.

Factor 9: Phased introduction

To minimise the inevitable economic disruption that a tradable permit program might cause, a phased introduction proved to be important in terms of the acceptance. This is especially true for a greenhouse gas emission trading program, and the RGGI is no exception as it reaches the end of its fourth control period in 2021. A phased introduction refers to the period that targeted reductions of emissions would take place and the levels of emission reductions that would, in theory, occur because of emissions trading. A third aspect of a phased introduction relates to sectoral coverage of the program. The industrial sector covered by the RGGI was fixed (i.e., stationary energy). The RGGI control periods that followed saw the level of emissions reduction gradually increasing.

External factor: Alternate policy

Alternative policies were the backbone of the RGGI approach to reducing emissions and action on climate change. The revenue raised from allowance auctions was distributed to the participating states, after the deduction of administration costs by RGGI Inc. The areas that this auction revenue was then passed on to were described by an analysis group as:

> General fund/State government funding – includes money used to fund state agencies, programs and other expenses not necessarily tied to RGGI program

activities, through use of RGGI allowance revenues as a contribution to meeting overall state budget requirements.

Energy efficiency and other utility programs – described further below. Renewable investment – includes grants to programs and investments focused on the development, distribution, and installation of renewable or advanced energy technologies (e.g. a program to support installation of rooftop photovoltaic systems).

Education, outreach, and job training – includes monies used for programs (i) to educate business and residential consumers about energy consumption and the availability of programs to reduce consumption, and (ii) train workers with new skills and knowledge in industries and activities that contribute to lowering energy use (e.g., energy efficiency measure installation) or the production and distribution of renewable or other advanced energy technologies.

Direct energy bill assistance – includes use of RGGI funds to reduce bills paid by consumers for electricity and heating/cooling. Most significantly, investments in this category were targeted to low-income households.

Other greenhouse gas reduction programs and program administration. The greenhouse gas reduction programs include a variety of expenditures aimed at reducing emissions – such as research and development grants for carbon emission abatement technologies, direct investment in green start-up companies, direct greenhouse gas emissions reduction measures (e.g., efforts to reduce vehicle miles travelled and programs to increase carbon sequestration), climate change adaption measures and investments in existing fossil-fuel fired power plants to make them cleaner and/or more efficient (e.g., installing pollution controls and installing technologies to increase plant efficiency).

RGGI program administration refers to RGGI auction proceeds used by each RGGI state to cover costs associated with the administration of the state's CO_2 budget trading program and/or related consumer benefit programs. (Hibbard et al. 2011, p. 18)

The distribution of funds from the allowance auctions in the first reporting period of the RGGI were estimated by Hibbard et al. as:

> EE (energy efficiency) and other utility programs audits and benchmarking – 48%, general fund/state government funding – 20%. Direct bill assistance – 14%, other GHG programs, education and outreach, job training and program administration – 11% and renewable investment – 7%. (2011, p. 20)

In to the second and third reporting periods of the RGGI program individual states report on the nature of the re-investment of auction proceeds. While the reporting criteria varies between states as a minimum there are auction proceeds going into the areas of energy efficiency (56% of cumulative investments between 2009-2018), bill assistance (15%), administration and RGGI Inc'. Clean and renewable energy (14%) and GHG abatement (9%) are investments that some states have additionally supported.

6.6 Design factor alignment with the constraints

This study has found that the relative importance of the design factors during implementation is found to have varied between the RGGI and the EU ETS. It has also been established that these factors can align differently with each of the constraints of acceptance, effectiveness and emissions reduction.

A strong alignment with the effectiveness of the program indicates that there is a correlation between the impact of a factor and the aims of the program. For example, the coverage of the RGGI was focused on the stationary energy sector. This provided a degree of clarity within the RGGI given the prior experience in the US with these types of programs. Programs like the LTP that specifically aimed at oil refineries and vehicle exhausts, and the US ARP that covered power stations across the US.

On the other hand, a factor that is found to be weakly aligned to a constraint may exhibit divergence from the immediate aims. An example in the RGGI is the alignment of the factor of governance with the constraint of effectiveness. The governance of the RGGI was initially a three-stage process that involved an existing regional body, the newly formed RGGI board and the legislative processes of the participating states. None of these bodies had direct oversight of, for instance, the setting of RGGI targets for emissions reduction. As a result, some disparities developed between states.

From the observations made in the study about the factors, a set of questions were developed in Chapter 3. The set of questions shown below are used to rank each factor in relation to an alignment with the constraints.

1. Did the factor appear in the original design of the program?
2. Is there a specific rule or set of rules that apply to the factor?
3. During the study has the impact of the factor grown in prominence.
4. Over the study does a factor's association with the constraints of acceptance, effective operation, and emission reductions correlate?

Table 44: Factor weighting table for the RGGI (1)

Factor	Legislation	Rules	Governance	Coverage (narrow)	Compensation	Phasing in	Targets
Weight for criteria 1	1	1	0	2	0	1	1
Weight for criteria 2	0	1	1	1	1	1	0
Weight for criteria 3	1	1	2	1	2	2	1
Weight for criteria 4	0	0	1	1	0	1	2
Totals	2	3	4	5	3	5	4

Table 45: Factor weighting table for the RGGI (2)

Factor	Allowance allocation	Compliance
Weight for criteria 1	2	1
Weight for criteria 2	1	1
Weight for criteria 3	2	1
Weight for criteria 4	1	1
Totals	6	4

The averaging of total values for the factor weightings shown above in **Tables** 42 **and** 43 reveals that the benchmark value to determine an important factor in the RGGI was, 4.

An association with effective operation in the scheme indicates that the factor was related to the normal or legislated behaviours of the liable entities in areas such as monitoring, reporting, compliance, and administration of allowance accounts.

The factors found to be strongly aligned to emission reduction in the study of the RGGI are legislation, compliance, rules, coverage (narrow) and compliance. Legislation in the RGGI takes a two-tiered approach as both the RGGI board and each participant state provide input. The joint contribution of the RGGI board is through the model rule and each state through developing the appropriate legislation. In the RGGI compliance is maintained by the administration of the COATS database and separate reporting to the US EPA. Surplus allowances in the RGGI are held by the states and retired after 3 years as allowances become excess or as the targets for emissions reductions are tightened (PACE 2011).

The coverage of the RGGI is single sector covering electricity generators with a capacity of 20MWs or above. With this relatively narrow coverage, the RGGI does not take advantage of the burden sharing arrangements that are typical in the EU ETS. Hibbard and Tierney (2011) also flag the risk of carbon leakage where emissions may shift to other non-participating states. The negative economic impact of the allowance auctions and subsequent increases in electricity costs is offset in the RGGI by the redistribution of revenue to the states for compensation and complementary policies.

Unlike the EU ETS where the free allocation of allowances provided an economic rent for participants, free allocation was not a priority in the RGGI. Allowances in the RGGI programs are principally auctioned. At the time of writing, there was a degree of consternation about how handle allowances on the various participant or investor balance sheets. As stated earlier, the GAAP, the IFRIC and the IASB have yet to establish agreed guidelines on emissions trading, a rate regulated activity (IFRS 2013).

Alternative policy is strongly recognised as external factor by the RGGI. As the revenues from allowance auctions are directed toward various energy efficiency projects. These projects are described as:

> …investment in energy efficiency programs, investment in community-based or private-sector installation of renewable or advanced power generation systems,

> direct reductions in electricity bills, funding of state government operations through allocation to state general funds, education and job training programs, and administration of the RGGI program or other greenhouse gas reduction initiatives. (Hibbard et al. 2011, p. 1)

Over time the greenhouse gas reduction initiatives have broadened to include programs that promote research and development in advanced energy technologies, electrification of vehicles and reduction of vehicle miles and tree planting to facilitate carbon sequestration. Comparing the RGGI and the EU ETS in relation to investment for emerging abatement technologies, the RGGI is seen to be early adopter of this concept.

6.7 Chapter summary

The study has found a degree of contextual divergence between the case studies. This divergence relates to how the initial allowances were allocated. In terms of governance, the RGGI is overseen by the board of RGGI Inc., which issues MoUs to the participating states. In the initial stages of the study, the RGGI states developed their own plans to implement the MoUs, based on the model plan developed by RGGI Inc. The plans must then in turn be ratified by RGGI Inc.

Over the second, third and current fourth control periods the board of RGGI have played a more coordinating role in this this ratification process. This be a similar role that the EC directives perform in the governance processes of the EU ETS.

The initial set of case study data that was selected for the RGGI came from a facility level and state-by-state basis. This data has been able to determine the emissions trends that developed within the RGGI over the first control period of 2009 to 2011. The data for the sub sequent periods has over time become accessible through the COATS database also and has been included in the study to mirror the process that was established in case study one on the EU ETS.

The stated aims of the RGGI were to stabilise emissions, which represented a reduction against the so-called business as usual (BAU) trend, the COATS data suggested that greenhouse gas emissions appeared to have dropped over the first reporting period of the RGGI. In the first control period, it was found that the ideals of the program had been met and, while some of the participant states increased their emissions, more states had reduced emissions or emissions had been stabilised. In the RGGI in total, emissions were reduced slightly, by 0.8%, in the first compliance period.

The material collected for the second and third control period indicates that emissions have continued to drop. This is important for the study as the structure of the RGGI provides some evidence for emissions reductions which can be linked to greenhouse gas emissions trading.

The recent data shows that between these control periods there was nearly a 15% reduction in emissions between 2012 and 2017. While this reduction exceeds the expectations of the program which were a 10% reduction by 2018 (EDF-IETA, 2014), Schamalensee and Stavins (2015) suggest that the programs cap on emissions have not been binding.

Table 46: RGGI second and third control period emissions

Total emissions	265,882,996.06 (second period, tons)	226,532,836.12 (third period, tons)
Emissions reduction and percentage change	39193984.65 (tons)	14.74%

Source: RGGI COATS (2020).

The data from COATS, when viewed in terms of greenhouse gas emissions trends, indicates that the RGGI was less affected by the GFC than the EU ETS. The results in the RGGI are less of an analogue of the GFC, given that the timing of the first control period put the RGGI into a recovery phase in terms of economic activity generally in the US.

The EU ETS also had a wider sectoral coverage compared to the single sector focus in the RGGI. Another difference to emerge from the programs is the targets that had been set for emissions reductions. The departure of New Jersey during the first control period and then its' return for the fourth control period may be related to concerns about economic stability.

The contrasts between the two main case studies are discussed in more detail in the comparative Chapter 7.

Chapter 7: Comparing the EU ETS and the RGGI

7.1 Introduction

Before Chapter 5, the prior literature and some other designs for permit programs have guided the investigation. The programs that have contributed to the study, such as US ARP, the UK ETS, the CPRS and the CCTP are mentioned briefly but are not the focus of this chapter. This comparative chapter is concerned with the performance of the two greenhouse gas case studies, i.e. the EU ETS and the RGGI.

The two main case studies were the subject of an in-depth analysis in the preceding Chapters 5 and 6. The case studies were selected apart from these other programs because their governing bodies were seen to have had experience in managing a range of other complicated issues. It was envisaged that this experience could be restructured to encompass effective programs for greenhouse gas emissions trading.

Structurally, the RGGI and the EU ETS share some design traits. A single body initially oversaw the design and regulatory aspects. In the case of the RGGI, this is the NEG-ECP and in the EU ETS, oversight is provided by the EC. In the programs, detailed planning and implementation was initially ceded to a lower level. In the case of the EU ETS, the initial allocation plans were developed at a national level. However, in phase two, the EC moved toward a burden sharing arrangement, which meant allocation plans were finalised at the EC level. In the RGGI, the participating states had a degree of autonomy in developing the legislation associated with implementation. The board of RGGI Inc' now oversee this aspect.

The data from the two main case studies provides evidence for the various design factors that are found to be important during the implementation and effectiveness of the programs. This study has used three constraints that can be impacted by these design factors. There constraints are acceptance, effectiveness and emissions reduction.

A group of common factors found to be important at the implementation stage of greenhouse gas emissions trading appear to a lesser or greater degree in each of the case studies. The impact that the factors have in each of the case studies is sometimes but not always aligned with the general requirement to reduce emissions. The data from the case studies indicates that the factors that are important for acceptance can have an adverse impact on reducing emissions.

Prior programs in the US, such as the LTP and the US ARP were singular in terms of coverage and had hard targets. The proposals for greenhouse emissions trading that have emerged from the Kyoto Protocol sought wide participation, particularly the EU ETS which covers 31 countries (EC, 2020). The initial wide coverage of the EU ETS has slowly expanded to introduce new participants from the chemical industry and aviation in the European Economic Area.

A comparative policy analysis is used frequently in the research when considering some of the differences between the schemes studied. In Europe, throughout the early negotiations for the Kyoto Protocol, the EC had initially opposed and later adopted a trading scheme. During the early Kyoto negotiations, a policy turnaround saw the EU embark on an ambitious undertaking.

On the other hand, in the US emissions trading had been at the forefront of market-based environmental regulation in the US since 1985 when the LTP began. At the time of the Kyoto negotiations there was opposition to greenhouse gas emissions trading at a federal level.

An example of how policy differences have emerged between the RGGI and the EU ETS is in relation to how allowances were initially allocated in the primary market. In the RGGI, a few allowances, 25%, were distributed through quarterly auctions. The number of auctioned allowances has grown to 90% in the RGGI. The RGGI now operates a containment reserves that sets an upper and lower price collar for allowances. In 2021, 10% of allowances in the cap will be placed into the containment reserve. The table below shows how the RGGI cap is adjusted to supply the reserve.

Table 47: RGGI allowances containment reserve

Year	RGGI allowance cap	RGGI adjusted cap	Containment reserve
2014	91,000,00	82,792,336	8,207,664
2015	88,725,000	66,833,592	21,891,408
2016	86,506,875	64,615,467	22,054,080
2017	84,344,203	62,452,795	19,782,803
2018	82,235,598	60,344,109	21,891,498
2019	80,179,708	58,288,301	21,891,498

Source: RGGI (2020).

In the EU ETS, allowances were grandfathered free of charge, based on historical levels of emissions. While this was the case in phase one of the EU ETS, auctioning was used in the later phases. In 2015 market stability reserve (MSR) was introduced so that allowances could be removed after a surplus of allowances forced prices to drop. In 2019-2023, the number of allowances held in the reserve will increase from 12% to 24% reducing the total number of allowances in circulation (TNAC). After 2023, allowances held in the reserve from the previous year's vintage will no longer be valid. The TNAC is calculated using the formula, TNAC = Supply – (Demand + allowances in the MSR).

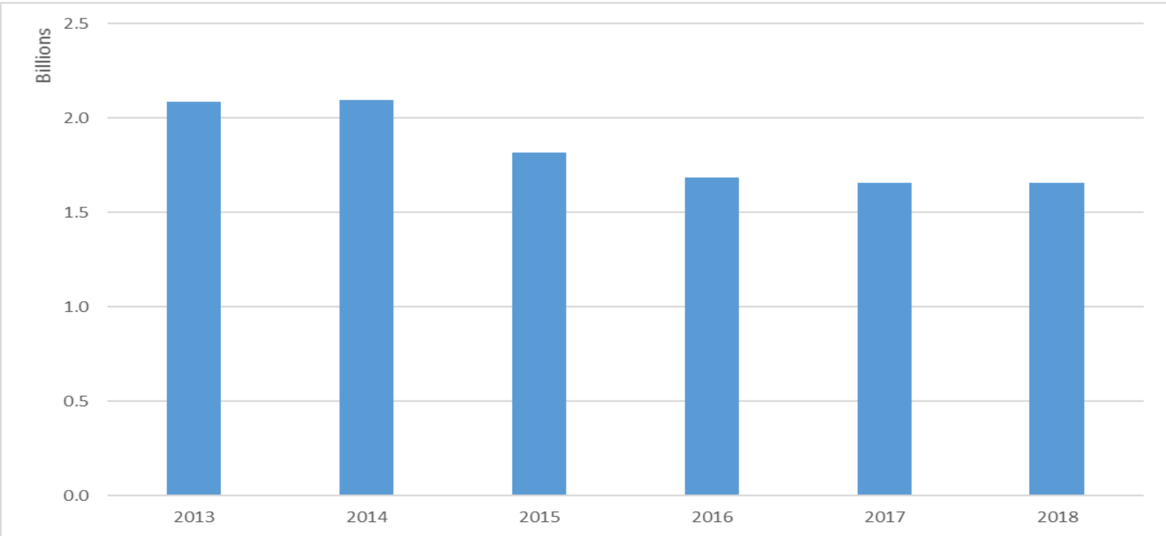

Figure 14: Allowance surplus in the EU ETS 2013-2018

Source: EC-DG Climate Action.

7.2 The case studies relative size and coverage

The UNFCCC receives annual CO_2-e emissions data associated with Annex 1 countries under the Kyoto protocol. The 2010 reporting by Annex 1 countries recorded a total of 23,143.60 million metric tonnes (mmt) of CO_2-e emissions (UNFCCC 2012). The emissions of the Annex 1 countries represented approximately 75% of the global emissions of CO_2-e of 30,824.18 mmt.

In 2010, the total coverage of the two case studies represented 2,134.53 mmt of GHG emissions, which represent 9.22% of the annual UNFCCC Annex 1 emissions. The EU ETS covered 1,932.45 mmt of CO_2-e (UNFCCC 2010), while the RGGI covered 203.96 million short tons (202.07 mmt) of CO_2 (US EPA 2012).

There are indications that the total emissions covered are dropping as caps are tightened and allowances are removed from circulation. Combining data from the end of the third RGGI control period (2017) and 2018 emissions from the EU ETS, the combined total covered by the two programs is estimated to be approximately 1,906.25 million metric tonnes, a reduction of 12%. As the reporting and reconciliation periods of the RGGI and the EU ETS do not coincide, this observation has not been rigorously tested.

In relation to the number of participants in each of the case studies, the RGGI is also the smaller of the two. Looking at the emissions covered and participant numbers in the programs, as shown in Table 64 below, the total covered by the RGGI is much less than that of the EU ETS.

Table 48: EU ETS/ RGGI 2010 total emissions covered and participants

Program	EU ETS	RGGI	Difference
Total emissions (2010) million metric tonnes (mmt)	1,932.45 mmt	202.07 mmt	1,730.38 mmt (89.54% more emissions covered in the EU ETS)
Number of participating regions	29 EU countries	9 US states	20 (68.97% more regions in the EU ETS)
Number of registered participants (2011)	12,330	211	12,119 (98.29% more participants in the EU ETS)

In the initial study of the EU ETS, the research covered phase one (2005-2007) and phase two (2008-2012). As time progressed, some updated material became available on Phase 3 (2013-2020). The governing body of the EU ETS is the EC, which coordinates many activities for member countries participating in the EU. In the case of the EU ETS, the focus of activity is the abatement of greenhouse gases, primarily CO_2, through greenhouse gas emissions trading that produce carbon markets for the allowances that are required.

For the case study on the RGGI, the initial research covered the first control period (2009-2011). Material was later added that reflects experience in the second (2012-2014), third (2015-2017) and fourth (2018-2021) control periods. The RGGI governing body was the board of directors, RGGI Inc. The board was comprised of environmental and energy department heads from the participating states. At the time of writing, most participating states had two board members; the exception was Delaware, which had a single representative.

RGGI activity is focused on the abatement of CO_2 from power stations through greenhouse gas emissions trading. This makes the investigation of the RGGI simpler than for the EU ETS, which was complicated by the number of countries involved and the emissions from several different industrial sectors.

The RGGI is a state based regional program that covers a heavily populated part of the north eastern and Mid Atlantic US. As with the EU ETS, in the early developmental stages of the program the number of direct participants in the RGGI has varied. In the RGGI, potential participants can remain on the sidelines and have an observer status as, was the case with Pennsylvania.

At the time of writing, there were nine RGGI participant states Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. New Jersey withdrew from the RGGI at the completion of the first control period and returned during the fourth control period.

While many new design challenges were overcome in the implementation of both programs, success in achieving the emission reduction goals has been consistent if somewhat limited in the early phases and control periods. As expected, the performance of the two main case studies has been heavily scrutinised by countries considering their own market-based approaches. Some alternative greenhouse gas mitigation strategies, such as carbon taxes, have been pursued elsewhere.

7.3 The reporting of GHG emissions in the main case studies

In the case studies, the identification of the initial level of emissions for individual or aggregate sources was the starting point to establish the level of any reductions. The process involves the analysis of a large and new reporting regime. Similarly, in the development of the new markets for CO_2 allowances the identification of the fundamentally important design factors is critical to the process. To this end, a new framework of three constraints has been developed in this study to achieve a comparison with the nine design factors that are also used in the study.

Reporting greenhouse gas emissions in the EU ETS

For the EU ETS, the directive EC 2003/87/EC of the European Parliament and amending council directive 96/61/EC, established a scheme for greenhouse gas emission allowance trading within the community (EU 2003). The first EC directive in its original form represented an ambitious plan and as a large platform for greenhouse gas emissions trading it had no precedent.

The initial articles in the directive were broad in scope and it has undergone revisions as the program moved through the first three phases. The range of issues covered by the directive included greenhouse gas emissions permits, NAPs, allocation, issue, and transfer of allowances, reporting of emissions, verification, penalties, competent authorities, registry and linking.

The case study on the EU ETS uses the CITL (now known as the EUTL) greenhouse gas emissions data to identify the level of compliance with emissions trading. The participant data from the covered industrial sectors was extensive. The covered sectors were power and heat, cement and lime, oil and gas, glass and ceramics and pulp and paper. In 2006, the power and heat sector accounted for around 69.76% of total emissions covered by the EU ETS (Hintermann 2010). The EU ETS CITL was established in 2005 and after the first reconciliation of allowances and emissions it became apparent that there was an excess of allowances.

In 2005, allowances for 2,096,444 kilo tonne (kt) of CO_2-eq were issued. The verified emissions for 2005 were recorded by the European environmental agency were 2,014,016 kt of CO_2-eq, resulting in an allowance excess of 82,428 kt. The trend of excess allowances continued into the 2009 compliance period, when allowances for 1,845,121 kt of CO_2-eq were issued in the EU ETS. The verified emission for 12,249 permit holders in 2009 was 1,773,482 kt CO_2-eq, representing an excess of 71,639 kt.

The excess of allowances and the resultant low allowance prices introduced another aspect into this study. This related to the effect other complementary policies, e.g. renewable energy targets and economic trends such as the GFC, and now COVID-19, may have been having on the level of greenhouse gas emissions.

There has been an obligation on each EU ETS member to introduce renewable energy sources that can provide offsets that are also tradable in the allowance market. Bohringer, Rutherford and Tol (2009) identified the potential for these complementary policies (e.g., renewables and energy efficiencies) to develop non-emissions trading markets with a separate price on carbon. The resulting split of these complementary markets away from emissions trading markets can lead to a distortion in both markets.

Reporting greenhouse gas emissions in the RGGI

In December 2005, seven US states signed the MoU that was to develop into the RGGI program for greenhouse gas emissions trading in the region. The RGGI compliance data is reported through COATS under the governance of the RGGI Inc.

Unlike the activities in the EU ETS, the aims of the RGGI program were casually linked to the aspirations in the Kyoto protocol. A simple aim of the RGGI was to start a system that could manage the data on emissions from entities covered by the RGGI. The process would need to track the distribution of allowances through auctions and any subsequent markets that developed. The RGGI board helped the states to create a common platform for handling emissions offset projects.

The accessibility and transparency of the RGGI allowance tracking system, COATS, is valuable as the program offers a much-needed view into a viable greenhouse gas ETS. The rules for the operation of the RGGI were developed by each participating state, although verification from the RGGI board is needed. In terms of complying units, the RGGI compliance summary report indicated that five units were listed as non-complying, i.e., 1.9% of registered participants (RGGI 2012).

The coverage of the RGGI (i.e., the stationary energy sector) was narrow and compliance has been high. The RGGI initially targeted the CO_2 produced by coal fired electricity generators with an output of 20MWs or more. Each participant is provided with a unique facility identification number known as an ORIS code. The ORIS codes are issued to each registered participant on a state-based order and emissions data is tabled on the RGGI website and made publicly available for downloading in the form of an excel spreadsheet.

In the RGGI, the revenue from allowance auctions has meant the program could support a range of complementary strategies on climate change mitigation. In the first control period of the RGGI, between 2009 and 2011, there were fourteen auctions for CO_2 allowances. At the time of writing, the proceeds from the auctioning of RGGI CO_2 allowances exceeded US$1.3 billion.

The intent was to distribute this revenue through the subsidisation of energy efficiency activities, to offset of energy costs and other investments. In 2012, RGGI Inc. reported the distribution of revenue as energy efficiency (66%), clean and renewable energy (5%), direct bill assistance (17%), greenhouse gas abatement and climate change adaptation (6%), administration (5%), and RGGI Inc. (1%).

The number of registered participants in the RGGI was identified in the account representative report. This report provides the number of participation permits that are issued. In December 2012 there were 263 registered participants. The CO_2 allowances in the RGGI represent one US short ton of CO_2. The first control period in the RGGI was completed at the end of 2011 and the full compliance data was released in 2012. The verified emissions within the covered sector of the RGGI for 2009 to 2011 were also recorded by the US EPA.

Over the first control period (2009-2011), emissions covered by the RGGI program totalled 382,064,547.67 short tons (346,603,127.34 metric tonnes). By way of comparison, the greenhouse gas emissions from the Australian stationary energy sector in one year (2011) were 290,800,000 metric tonnes (Australian Government 2013b).

The inclusion of the stationary energy sector to the exclusion of other sectors may be a negative in terms of distributing the economic burden. In the RGGI, this narrow coverage is a recognition of the large contribution the sector makes to greenhouse gas emissions. The narrow coverage also takes advantage of the reliability of accounting for greenhouse gas emissions across the sector. The administrational efficiencies of a relatively narrow coverage, as in the RGGI, may be a compensating consideration in relation to the distributional efficiencies of wide coverage, as in the EU ETS.

Murray and Maniloff (2015, p. 588) suggest that the RGGI has accounted for a 19% drop in emissions in the region. While their research also found that counterfactually, i.e., without the RGGI program in place, greenhouse gas emissions in the region would have risen by 24%. In reaching their conclusion that emissions had dropped by a significant amount over a relatively short period of time, the researchers acknowledge that several external factors had also contributed to an overall downward trend in greenhouse gas emissions in the US.

They identify three processes that are putting downward pressure on emissions, these are firstly, what Murray and Maniloff describe as the great recession or GFC, secondly, new reserves of natural gas, and thirdly, alternative policies such as renewable portfolio standards (RPS).

An RPS is usually a mandatory introduction of renewable energy sources into the energy mix. The targeted inclusion of renewable energy replaces, to a degree, the exit of fossil fuel sourced emissions that are a result of cap and trade. All the RGGI states introduced mandatory RPSs except for Vermont where participation in the RPS was voluntary.

Murray and Maniloff have also considered the quantitative and qualitative emissions accounting approaches taken other prior research projects that were principally looking at the EU ETS. Murray and Maniloff (2015, p. 584) cite Ellerman and Buchner (2008), who considered the decline of greenhouse gases in the European region and how much of that decline could be attributed to the EU ETS. Ellerman and Buchner observed the effect of weather, energy markets, energy efficiency programs and the emissions intensities of alternative fossil fuels.

In relation to phase one and phase two of the EU ETS, Murray and Maniloff (2015, p. 585) also cite Bell and Joseph (2015) who found that the largest driver of emissions reduction in the European region was the GFC. The fracking boom in the US that led to reduced prices for natural gas used in electricity production is proposed as the key difference between the US and European examples.

At the time of writing, the RGGI emissions caps are adjusted downward on a yearly basis. The RGGI now operates with cost containment reserve (CCR) allowances to be released if the price of allowances rises above US$4. Even if the CCR allowances are used to cap allowance prices, then the RGGI still aimed to reduce emissions between 2014 and 2020 by around 14%.

Schmalensee and Stavins (2015) reported on the case of the RGGI where the emissions cap was set to drop by 2.5% each year from 2015 until the target reached a level of 10% of 2009 levels in 2019. They also reported that over the third phase of the EU ETS, between 2013 and 2020, the target for emissions reductions been set at 20% below 1990 levels.

Narassimhan et al. (2018) have found that that an average emissions reduction of 4.35% occurred in the EU ETS over the first two phases (2005-2012). While in the RGGI jurisdictions, Murray and Maniloff (2015) have estimated that between 2009 and 2014 emission reductions were in the order of 24%.

7.4 A framework for the design factors

The conceptual framework described in Chapter 1 of this study suggests that the original design parameters will change as distortions occur due to internal and external forces. These distortions require changes to be made to the original design parameters. The various design parameters are described by the factors identified in this study. The compilation of these factors has formed a structure through which the case studies have been assessed.

The framework described above in terms of the EU ETS, differs slightly for the RGGI as there were no plans to widen the sectoral coverage of the RGGI. A similarity that did become apparent between the two case studies, as described in the conceptual framework, were the progressively deeper emissions cuts in later stages.

In the case of the EU ETS, the design factors associated with acceptance are ranked more highly than the comparable factors in the RGGI. While in RGGI the factors related to effective operation were embedded more quickly, when compared to the EU ETS. The position of the RGGI as a viable carbon market was established in Chapter 6, while in Chapter 5 on the EU ETS, it was apparent that a stable carbon market was slower to develop.

In the EU ETS, governance stands out as an important factor in terms of effective operation. While in terms of emissions reduction, the rules of the EU ETS are a significant factor. Strong governance allowed the EU countries to agree on burden sharing arrangements, where those best positioned to reduce emissions could do more than others to meet their Kyoto targets. The rules in the EU ETS were of a flexible nature and this became important to compensate for the dynamic nature of the program.

The third ranked factor in terms of effectiveness is legislation. The EC is the legislative body for the EU ETS, so legislation (through the issuance of directives) was carried out in an already established environment. In the developmental stages of the EU ETS, the distribution of revenue from the trade in allowances was not a priority. Therefore, the factor related to allowances (as a financial asset) has been rated the lowest of the effective operation factors.

In terms of emissions reduction, a highly rated factor was coverage (narrow), while the easily attained targets for the reduction of emissions in the EU ETS were achieved it remains difficult to conclusively attribute the reductions to the EU ETS. As previously mentioned, there were other forces contributing to the falling emissions across the EU such as the GFC and now in a similar fashion the COVID-19 pandemic.

The sectoral coverage of the EU ETS was ambitiously wide for a pilot program. As the EU ETS approaches the end of Phase 3 in 2020, coverage has expanded further to include at least two new sectors. This widening sectoral coverage aligns with the economic imperatives of tradable permits. It is a widely held view that broader sectoral coverage distributes the financial burden of compliance and opens the program to more innovative technologies.

Hintermann (2010) has stated that price of allowances in the first phase of the EU ETS were somewhat volatile, reaching a high of around €31 per tonne in 2006 and then a low of €0.0 in 2007. The average price of allowances over the first phase of the EU ETS was €12.39.

As described, over the period of this study the efficiency of the EU ETS has been diminished by a surplus of allowances. This surplus has been linked to a generous initial allowance allocation and the closure of some older facilities. These closures, particularly when allowance prices were high, sometimes resulted in windfall profits for the owners who could sell their allowances.

While the uncertainty associated with the ongoing impact of the GFC may have prevented structural changes from occurring within either of the ETS in the study, the unusual economic conditions allowed some unique observations to be made. In the period of the GFC the study was able to see first-hand the downward pressure on greenhouse gas emissions in the EU ETS. In the RGGI greenhouse gas emissions were seen to stabilise, as desired, in more positive economic conditions.

When comparing the EU ETS and the RGGI, it became apparent that there was an inconsistency in relation to the design factors that could be associated with effectiveness, with only legislation and compliance found to be common factors in this classification.

7.5 Emissions under the GFC

The impact of declining economic activity under the GFC resulted in a decline of greenhouse gas emissions is supported by the $I = PAT$ equation (Holdren 1991) and later in relation to the Kaya identity (Kaya & Yokobori, 1997) that related to the greenhouse gases more specifically. The effect of the economic downturn on the EU ETS and the RGGI has been observed by Schamalensee and Stavins (2015) and Murray and Maniloff (2015). Bayer and Alkin (2020) also comment on the GFC and the low allowance prices that coincided with declining greenhouse gas emissions in the EU ETS.

At the time of writing, COVID-19 is slowing economies as governments impose lockdowns, close borders, and suspend industry. Shakil et al. (2020) have found that research on greenhouse gas emissions and COVID-19 is developing in four broad clusters. They identify the COVID-19 related research clusters as: 1) environmental degradation, 2) air pollution, 3) meteorological factors, and 4) temperature.

Other research looks at the temporary reduction in CO_2 emissions because of the pandemic and the need for putting in place real time monitoring to observe daily trends (Le Quere et al. 2020). Wang and Wang (2020) examine the possibility of greenhouse gas emissions rebound as countries emerge from the pandemic. They cite the emissions rebound the in 2010 after the GFC in 2008, where on a country by country level lower average income was said to correlate with a larger rebound in greenhouse gas emissions.

The GFC was responsible for a sharp dip in the emissions curve across the EU. Due to the EU ETS's learning by doing status, at around the time the GFC was having its greatest impact on communities and emissions, the factors associated with acceptance in the EU ETS became particularly prominent. It has been established that the factors that have a strong alignment with the constraint acceptance are likely to be associated with less than optimum emissions reductions. In other words, the more weight they are given, the lower emissions reductions will be.

A theoretical advantage of greenhouse gas emissions trading was the flexibility in setting emission reduction targets. This flexibility has not been apparent in practice when dipping economic conditions would allow targets to be adjusted. The combined effect of an emerging EU ETS and the GFC could have provided an opportunity to take advantage of the flexibility of emissions trading. The way allowance allocation was taking place could have moved to auctioning, as is now the case. Targets for emissions reductions could have been shifted to reflect a steeper emissions reduction pathway.

The emissions reducing effect of the GFC was to disguise some aspects of attributing greenhouse gas emissions reduction. Despite these difficulties, Bayer and Aklin (2020) estimate an emission reduction of between 8.1% and 11.5% over the first two phases of the EU ETS.

In the initial deliberations on an appropriate market-based response, such as emissions trading, it was foreshadowed that the cost of mitigation could be in the order of -1% to 3.5% of GDP. With a central estimate of 1% for mitigation consistent with a 550 ppm CO_2-e stabilisation level (Stern 2006). The story that unfolded from 2008, as the GFC slowed in most economies, is not clear in terms of the impact trading may have had on GDP. From mid-2009, the economic indicators in the UK and Germany also started to return a positive inclination.

In the years immediately following the global financial crisis, Baily, and Elliot (2009) observed that economic indicators in the U.S. started to show signs that in terms of the GFC the worst for the US may have been over in 2009. Schamalensee and Stavins (2015) suggest that in the US the economic recession and drastic declines in the price of natural gas the cap on emissions in the RGGI ceased to be binding. They observed that the impact on allowance prices was a fall from $3/ton in 2008 to $1.86/ton during 2010 and then recovered to $5.50/ton in 2015.

Financial indicators in the US have been drawn upon for comparison in the second case study on the RGGI. The RGGI states' GDP is chosen to provide an insight to general economic trends in the region. The data for the a table showing RGGI states' GDP was obtained from the online records of the US Department of Commerce and its Bureau of Economic Analysis (BEA).

The RGGI program was established, in an operational sense, in 2009, about the time he RGGI GDP exhibited an upward trend. The emissions in the RGGI participant states do, in some cases, follow an upward inclination, representing increased emissions. In as many instances, however, the emission trends of the RGGI participant states were downward, representing a lowering of emissions. As shown below in Figure 15, a divergence appears to exist between the upward trend for RGGI states' GDP and greenhouse gas emissions over the same period.

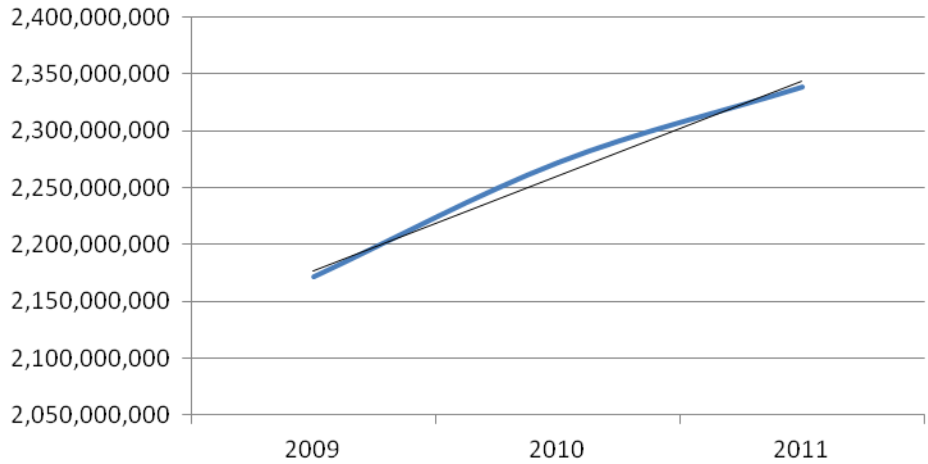

Figure 15: RGGI states' GDP US $m (adjusted for inflation)

In the first and second phases of the EU ETS, the level of emissions had a strong correlation with GDP in the region. In the RGGI case study the overall level of emissions was shown to have steadily decreased while at the same time GDP rose.

7.6 Chapter summary

In both case studies, the aim was to get full compliance in the covered sectors. This aim is assessed against the actual performance of the participants. The assumption in designing cap and trade is that if the participants are complying then the emission reduction targets can be met.

For the EU ETS, the compliance and emissions data were obtained for each country and indicated that there was a decline in emissions over the first stage of the EU ETS. The problem of a large excess of allowances in the first two phases of the EU ETS meant that compliance by the participants was too easily achieved. It became apparent that the EU ETS emissions data was influenced by the GFC and European zone financial crisis.

Canadell et al. (2007) have identified a link between increased emissions and increasing global economic activity, although others (Coers & Sanders 2012) suggest that this link may be strongest only in the short term while the economic conditions that existed under the GFC begin to improve. They also believe that reversing the trend could also possible where economic growth is attainable while greenhouse gas emissions fall. The

EC reported that between 2011-2018 emissions continued to fall across the EU ETS and the program was responsible for an almost 19% reduction in greenhouse gas emissions.

In the RGGI, an examination of the reports listed in the COATS tables indicates that the RGGI program had, in the first control period, achieved the objective of establishing a record of participant emissions and CO_2 allowance tracking. The initial dataset for the study was selected at both an individual facility level and on a state-by-state basis. This process established the emissions trends in the RGGI over the first control period of 2009 to 2011.

The COATS data indicated that, overall, there had been a high level of compliance by participants in the RGGI. The study also finds that greenhouse gas emission reduced or had been stabilised. In the RGGI in total over the first control period, emissions were reduced slightly, by 0.8%. The RGGI reported that over the second and third control periods emissions fell by almost 15%.

This study has established a wide divergence between the two greenhouse gas case studies in relation to the coverage of the programs and how the initial allowances were allocated. Another difference to emerge between the programs related to the targets for emission reductions. The EU ETS targets were aligned to the Kyoto protocol and ambitious when compared to the less ambitious emissions stabilisation targets of the RGGI.

Despite these differences, or in some cases because of them, the case studies provide important background data about the possible design of a program for greenhouse gas emissions trading. In relation to the distribution of allowances in the EU ETS, there is a move toward the elimination of high levels of excess allowances. There are also plans to move toward a greater level in the auctioning of allowances, from 10% to 50%. In the case of the RGGI, significant funds have become available from auctioning of allowances. This auction revenue is redistributed by each state through general funds.

In respect to each other, the EU ETS and the RGGI were at different staged of development due to the staggered start times and inherent differing economic circumstances. None the less, an important outcome for both is the discovery of a price for allowances. In the two main case studies, an allowance either represents a metric tonne of the greenhouse gases (EU ETS), or the slightly smaller (0.93%) US short ton (RGGI).

This outcome supports the theory that fluctuations in economic activity introduce corresponding fluctuations in the intensity of greenhouse gas emissions. It is an imperative for future designs to be able to respond to external factors that add to the complexity of determining the level of emission reductions attributable to the programs.

This situation has been investigated by a number of current studies considering the relationship between the emissions in a region and the sudden economic shocks brought on by the COIVID-19 pandemic.

The discussion in this chapter illustrates how ideological differences can influence the treatment of some important design factors at the expense of others. The EU ETS was, in the early phases of the program, a pilot scheme and reflected a desire by the European community to take the learning by doing approach. This approach was underpinned by the free allocation of the initial allowances. Conversely, from the start-up of the RGGI, participants were required to buy allowances at regular auctions.

It is a widely held belief that the burden of greenhouse gas emissions reduction should be spread as widely, over an economic region, as is feasible, to lower the cost of compliance to each participant. The EU ETS has a wide sectoral coverage compared to the single sector focus of the RGGI.

The development of the necessary policies and legislation for greenhouse gas emissions trading is often, but not always, conceptualised at a national level. The somewhat unknown impact of a carbon price signal is the principal stumbling block, although experience in the EU ETS and the RGGI has, in the longer run, resulted in relatively low prices for allowances. These low prices and low emission reductions reflect the impact that the factors of acceptance have had in areas such as coverage, targets, and allowance allocation.

The research questions in this study seek to inform us about the constraints and the design factors that are fundamental to the introduction of greenhouse gas emission trading. The prominence of these factors was established in both the EU ETS and the

RGGI and viewed in a comparative light. An interpretative assessment has been carried out to describe each factor and its importance in terms of the constraints of acceptance, effectiveness and emissions reduction. Acceptance factors are thought to be damaging to the ability of a program to reduce emissions. This premise and answers to the research questions are discussed in the concluding Chapter 8 to follow.

Chapter 8: Research questions and results

8.1 Introduction

Chapter 8 concludes the study by considering the three research questions in Sections 8.2, 8.3, 8.4 and 8.5. Section 8.6 sums up some of the key differences between the case studies. Section 8.7 briefly reflects on the limitations of the study reflecting feedback from a few different sources. Some directions for future study are pointed out in Section 8.8. Section 8.9 then summarises the study.

8.2 The research questions

The three main aims of this study were to firstly, establish whether the experience of the US ARP had translated into the programs or greenhouse gas emission trading; and secondly, to flesh-out the key design factors in relation to the constraints that shape policy for this market-based mechanism. Thirdly, the study asks whether it can be shown that the factors associated the acceptance of the greenhouse gas emission trading schemes has hindered large scale cost-effective greenhouse gas emission reductions.

The research questions that were developed are:

1. How have the lessons of the US ARP been translated into the later programs for greenhouse gas emissions trading?

2. Do the constraints and design factors used in the study align in a similar fashion across each scheme and what is the impact of any differences?

3. Can it be shown that the factors aligned with acceptance of an ETS may reduce the schemes ability to mitigate greenhouse gas emissions?

8.3 Research Question 1

How have the lessons of the US ARP been translated into the later programs for greenhouse gas emissions trading?

Many, but not all, of the design elements that proved successful in the US ARP were repeated in the designs for greenhouse gas emission trading that were compared in the study. As the theory suggested, in practice it can be shown that greenhouse gas emissions trading can offer a cost-effective method to mitigate greenhouse gas emissions. The evidence found in this study suggests that the capacity for emissions reduction exhibited by the US ARP was achieved but at a lesser level in the case studies on greenhouse gas ETSs.

The early stages of both the EU ETS and the RGGI were characterised by unstable and often low prices for allowances. Low prices reflect that the limit on emissions, or caps, were not binding and excess allowances were typical in both case studies. As the EU ETS approaches the end of Phase 3 and the RGGI the end of the fourth control period, allowance prices are approximately €25.15 (Markets Insider, 2020) and $5.75 (rggi.org, 2020), respectively. The US EPA website showed that in 2019 allowance prices in the SO_2 spot market ranged between US$63.75 and US$293.75.

A comparative study by Haites et al. (2018) suggested that a double benefit is forthcoming if allowances are auctioned and part of the revenue from the auctions are re-invested in alternative reduction policies.

A strong correlation exists between greenhouse gas emissions trading and the phased introduction of SO_2 emissions trading. A phased introduction relates to the path for emissions reductions and the proposed coverage, either of which can be increased in a staged manner. Other correlations relate to the accurate measurement of both the SO_2 and greenhouse gas emissions and the initial free allocation of some allowances based on grandfathering.

A key element related to the effectiveness of the US ARP was the ease with which low cost abatement was achieved. Costs were minimised because participants easily made decisions about fuel switching or existing emissions scrubbing technologies. Similar hope was placed on carbon sequestration which was an important theoretical alternative for greenhouse gas emissions reduction. Small scale sequestration plants are an established technology and there are ongoing greenhouse gas trials in place. The large scale carbon sequestration required for the stationary energy sector has not yet been technically or commercially viable.

The RGGI is a sub-national scheme from the US that, in a design sense, has been influenced directly by the prior experience of the US ARP. In this regard, the design of the RGGI is aligned with the models for emissions trading that can be found in the tradable permit literature. The RGGI emerged as the more economically efficient program, mainly due to the auctioning of allowances in a single sector, i.e., stationary energy.

The summary Tables 49 and 50 presented below, show the design features from the US ARP SO_2 emissions trading program that appear to be transferrable to greenhouse gas emissions trading for CO_2. These summary tables were developed from a more detailed set of tables that are in Appendix C, Tables 66 and 67 (Group 1 1998-2005), Tables 68 and 69 (Group 2 2011-2013). The tables in Appendix C are a more comprehensive listing of the features that are transferable, but also list elements of the US ARP where little or no evidence was found for their importance in the EU ETS and the RGGI. The summary tables are used to collect the design features from the US ARP that were relevant for the design of the comparative study of the two greenhouse gas programs.

Table 49: Summary of transferrable factors Group 1 Literature (1998-2005)

1	Emission targets achieved – Initially small reduction targets in the EU ETS and stabilisation goal in the RGGI
2	Allowance allocation – EU ETS free allocation initially and moving toward auctions. RGGI auctioned > 90% allowances.
3	Compliance – Achieved in both EU ETS and RGGI
4	Rules – e.g., penalties for non-compliance
5	Targeted the electricity sector – EU ETS included electricity and several other sectors. RGGI electricity only.
6	Phased introduction
7	Cost effectiveness i.e., lowered the cost of compliance
8	Fostered innovation
9	Enhanced environmental goals
10	Inherent flexibility – fuel switching, trade between participants and banking of allowances.
11	Self-reporting to public database

Table 50: Summary of transferrable factors from Group 2 literature (2011-2013)

1	Price volatility – allowances were removed from the markets in the EU ETS and the RGGI
2	Cost effectiveness difficult to assess as there were no reference cases
3	Thereat of policy reversal due to changing political landscape
4	Banking increases temporal flexibility
5	Banking allowed smoothing of allowance price variations
6	Clear rules for monitoring, reporting and verification
7	Auctioning may be superior to free allocation
8	A decentralised (state based) system may benefit due to a lesser number of sources
9	Penalties for non-compliance set in statute
10	Older facilities disadvantaged as compared to newer facilities built under more stringent standards

The evidence found indicates that many of the principles of SO_2 emissions trading were applied directly to trading programs for CO_2. In contrast, the evidence found also indicates that a significant number of the factors found in SO_2 trading do not appear in the case studies on CO_2 trading.

One element that is not considered while looking for evidence in the Group 1 (literature from 1998-2005) and Group 2 (literature from 2011-2013) tables shown above is the political background. In contrast to many greenhouse gas, ETSs that have been designed, SO_2 trading eventually developed a level of bipartisan support in the US.

The broad grouping of the design factors under the three constraints is discussed below in Section 8.4, there are indications that the nine factors found important for CO_2

emissions trading reflected factors found in the earlier US ARP for SO_2 emissions trading. While recent indications from the CCTP for CO_2 are that the factors that were important in the greenhouse gas emissions trading, case studies remain important in the newer programs.

8.4 Research Question 2

> *Do the constraints and design factors used in the study align in a similar fashion across case studies, and what is the impact of any differences?*

The background material covered for this study, on the predecessor programs for cap and trade, provided a framework of design factors in the comparison that resulted. The evidence suggests that these factors are strongly influenced regional differences. Regional differences can relate to prior experience with tradable permits, economic recession, a reliance on energy from fossil fuels and alternative emission reduction policies. In each of the programs in this study, these regional differences did to a degree influence the alignment between the design factors and the constraints.

The alignment of the trading scheme design factors in the study has been found to be a product of the focus of the program. A program in the early stages is likely to be focussed on the constraint of acceptance. The constraints, as defined in Chapter 1, Section 1.4, are acceptance, effectiveness, and emissions reduction. The design factors used in the study are aligned to the constraints as shown in Table 18, Chapter 3.

The nine design factors used are: legislation, governance, rules, compliance, allowances, emission reduction targets, coverage, compensation, and a phased introduction. As the programs gained experience with trading, the alignment of the factors has changed as the focus of the programs shifted from acceptance and effectiveness toward emissions reduction.

As mentioned above, Table 18 exhibits the results of assigning a weight to each of the design factors in terms of their fit with each of the constraints. The weighting assignment process is described in the methodology Chapter 3. The factor weighting process is also followed in the case study chapters, Chapter 5 on the EU ETS, Tables 29 and 30, and in Chapter 6 RGGI, Tables 42 and 43.

The tables from Chapter 3 show that in a more general sense and in relation to the constraint of acceptance, the strongly aligned design factors that can be linked to this constraint are compensation, coverage, and legislation. In a similar fashion, the strongly aligned design factors that can be linked to the constraint of effectiveness are governance, compliance, legislation, and rules. Strongly aligned design factors that were linked to emissions reduction are legislation, rules, targets, and compliance.

From chapters 5 and 6 the high ranked factors are shown below.

Table 51: EU ETS prominent factors (phase 1)

Important factors	Legislation	Rules	Governance	Coverage (wide)
Score	7	6	5	5

Table 52: RGGI prominent factors (control period 1)

Important factors	Allowance allocation	Coverage (narrow)	Governance	Compliance
Score	6	5	4	4

The tables above show prominent factors in the programs at or soon after start-up. During phase 1 of the EU ETS, legislation and rules are deemed to be the two highly rated factors. In the first control period of the RGGI, the two highly rated factors are allowance allocation and a narrow coverage. The factor of governance was the third ranked factor in both case studies.

Over the same period, i.e., phase 1 and control period 1, the lowest ranked factors for each of the case studies are shown in the tables below. These factors show a greater variation across the programs and are instructive about the early focus of each program. In the EU ETS, the lower ranked factors are compliance and targets, this outcome shows that the EU ETS was leaning toward acceptance of the program. This was particularly evident in Phase 1 and Phase 2. In Phase 3, compliance to meet more stringent caps have become a priority as coverage expanded. So, effectiveness and emissions reduction are becoming more of a priority in Phase 3.

For the RGGI, the low ranked factors are compensation, legislation, and rules. The low ranking of compensation reflects the focus of the program on auctioning allowances. Legislation and rules also receive a low ranking which is more related to the somewhat inconsistent approach that was a result of the individual states making their own decisions about these factors. In contrast to the EU ETS, the coverage of the RGGI remains fixed.

The ranking system used in the study struggles to account for the design factor of allowance allocation. Allowance allocation sits in the middle ground for both programs when looking at the factor weighting tables used in Sections 5.6 and 6.6. An inconsistency develops in relation to allowance allocation because it used differently across each of the case studies, i.e., for compensation (issued free initially) in the EU ETS and for emissions reduction in the RGGI (through auctioning).

Due to low prices and easily attained targets, both programs have introduced a methodology to manage an excess of allowances and subsequently the price of allowances. A price collar approach is applied in the RGGI in what is known as a cost containment reserve while the EU ETS operates a market stability reserve.

Table 53: EU ETS low ranked factors (phase 1)

Factor	Score
Compliance	3
Targets	2

Table 54: RGGI low ranked factors (control period 1)

Factor	Score
Compensation	3
Legislation	2
Rules	3

Over time in the study, it can be shown that the focus of the programs has shifted in relation to the alignment between the factors and the constraints or objectives at the time. In Table 55 below, the degree to which this alignment has shifted is described. The alignment is considered at start up (Phase 1 and control period 1) and during the current stages (Phase 3 and control period 4).

Table 55: Factor alignment during phases and control periods

Factor	EU ETS Phase 1	RGGI control period 1	EU ETS Phase 3	RGGI control period 4
Legislation	Strong	Weak	Strong	Moderate
Governance	Moderate	Moderate	Moderate	Strong
Rules	Strong	Weak	Strong	Moderate
Compliance	Weak	Moderate	Strong	Strong
Compensation	Moderate	Weak	Moderate	Moderate
Allowances	Weak (Free allocation)	Moderate (Auctioning)	Moderate (Auctioning)	Strong (Auctioning)
Targets	Moderate	Weak	Moderate	Moderate
Coverage	Moderate	Weak	Strong	Weak
Phased introduction	Moderate	Moderate	Moderate	Moderate

Table 55 above shows that as the programs have progressed through the various stages' factors associated with emissions reduction have become more prominent. The more flexible factors associated with acceptance have also become stronger but not as uniformly as the emission reduction factors. This indicates that both programs have undergone a change in focus from acceptance in the case of the EU ETS and effectiveness in the case of the RGGI, toward a focus on emissions reduction.

8.5 Research Question 3

Can it be shown that the factors aligned with acceptance of an ETS may reduce the schemes ability to mitigate greenhouse gas emissions?

The synthesis of the data on market-based environmental regulation highlighted a group of factors that are important in terms of a standard scheme design. Evidence has been found that suggests these factors can be typically related to either effectiveness, the potential for reducing emissions or the acceptance of the tradable permit programs. The various factors of scheme design have been compared to see how they have affected performance. A trend was observed in a group of design factors that are important for emissions reduction and gaining acceptance of greenhouse gas emission trading schemes. The data indicates that the acceptance factors can have a negative relationship with the desired outcome of emissions reductions.

Table 56: Top 4 factors alignment to the constraints

Acceptance	Effective operation	Emissions reduction
Compensation	Governance	Legislation
Coverage (wide)	Compliance	Rules
Legislation	Legislation	Targets
Governance	Rules	Compliance

The factors that are strongly linked to acceptance, effective operation and emissions reductions are shown in Table 55 above. In terms of acceptance, the factors shown to be strongly aligned with this constraint are, compensation, coverage, legislation, and governance. In contrast, the factors that are strongly aligned to emissions reduction are legislation, rules, targets, and compliance.

A spread of the weightings was assigned to the design factors to reveal their importance in terms of either acceptance, effective operation, or emissions reduction, it emerged that this importance is not uniform. This finding was influenced by the fact that designs for greenhouse gas emissions trading are shaped by external forces such as alternative policies and underlying economic trends. There needs to be careful examination of any policy for greenhouse gas emissions reduction in terms of the incongruent correlation that the study has found between the factors more strongly aligned to acceptance and their impact on actual emissions reductions.

The factors associated with acceptance are principally applied in the early stages of a program’s implementation. The two highly ranked factors in the study are compensation and coverage. Inherent in these two factors are the attractive characteristic of flexibility.

Compensation may come in the form of free allocation of allowances or direct payments from the programs revenue to offset rising prices. The trend in the case studies has been toward lowering the level of compensation to allow the emission caps to become binding. As described in the preceding Section 8.4, allowance surpluses, low prices and easily attained targets combined to lessen the need for compensation. Coverage in the study is shown to be a double-edged sword in that it can be narrow, focussed on stationary energy, or wide to spread the cost of compliance. A narrow coverage has been shown to be an effective way to operate a program such as the RGGI. The EU ETS on the other hand had wide coverage from the start and it continues to grow. Wide coverage in this instance was at first seen to be a confounding factor as some countries carried considerably more of the emission reduction burden. As the program progressed, older facilities simply closed, and emissions leaked through cross border energy trades with neighbouring regions. An expanded coverage introduces a broadening EU ETS emission catchment.

The study has shown that the factors aligned toward the acceptance of a scheme may not necessarily reduce a schemes ability to reduce emissions in the long run if they can be adjusted over time as parameters change (e.g., management of excess allowances), or external forces impinge (e.g. fuels prices drop, a GFC or COVID-19 pandemic).

8.6 Differences between the case studies

When the UNFCCC put forward cap and trade greenhouse gas emissions trading as a path toward a coordinated way to reduce emissions, it was envisaged that a series of large trading programs could be linked. Along the way, significant difficulties have been encountered in achieving the necessary international agreement.

Generally, the findings of the study reveal that, in relation to the emissions of individual countries and regions, in some cases there was a reduction in emissions. In other individual countries and regions, however, there were emissions increases. This discrepancy was particularly evident in the early stages of both the case studies.

For the period 2005 to 2011, the study found that in absolute terms, emissions across the EU ETS fell by 11%. The level of emissions reductions for each nation ranged between 0.01% and 31.34% (i.e., an average of 13.5%). As reported in Chapter 7, the EC figures indicate that between 2011-2018 emissions covered by the program fell by almost 19%.

As a pilot cap and trade program, it was anticipated that there would be a degree of 'learning by doing' in the EU ETS. This learning was evident in the distortions to the carbon market, partly due to the initial free allocation of allowances. A flood of allowances resulted in oversupply and the price of these allowances has remained low. Emissions in the EU region were also reduced by the GFC, which forced a contraction of economic activity and, as a result, the level of greenhouse gas emissions dropped in regions actively involved in the EU ETS.

In the first compliance period for the RGGI, it has been established that, in absolute terms, emissions had fallen by 0.8%. The aim of the RGGI following this period was to stabilise emissions to 2014 (Murray & Maniloff 2013). In the RGGI, half of the participating regions experienced emissions reductions, while the other half experienced stable emissions or emissions increases.

The level of emissions reductions in five states varied from 2.8% to 30.65%. In the remaining RGGI states, where emissions were stable or increased, their contribution to increased emissions varied from 0.0% to 21.49%. In the last two control periods of the

RGGI, it was reported that there was a nearly 15% emission reduction across the program.

In the RGGI, the GDP for the RGGI states were used to compare economic activity and emissions. In this case, less affected by GFC conditions, emissions abatement could be directly attributed to greenhouse gas emissions trading. The impact of the GFC on the EU ETS made this type of examination difficult, although the emissions reductions aside from GFC conditions, in that program have now been identified by several researchers.

This study does not examine the correlation between emission trends and GDP generally. In China, a reduction policy has been in place for some time on the burning of fossil fuels. Garnaut (2014) observed that in China, emissions from fossil fuels have decreased while GDP in China has also risen. The cases studies also reflect this trend as they emerged from the GFC. The potential for a retaliatory rebound effect after a global recession such as the GFC is currently being viewed considering the COVID-19 pandemic.

Prominent in the EU ETS is the wide sectoral coverage that it is hoped will distribute the economic burden of emissions reduction. Unique to this program is a burden sharing agreement that is a form of cross border cooperation between the participating nations under the coordination of the EC.

The design of the RGGI represented a departure from the design of the EU ETS in some important ways. It was a smaller program in terms of the number of participants and the number of jurisdictions covered. The RGGI began four years later than the EU ETS and as a result the period over which the initial emissions data was available was initially shorter. The RGGI was a single sector scheme that covered only the stationary energy sector, i.e. fossil fuelled plants used for electricity generation. The US ARP also concentrated on the US electric power generators, which, it seems, expedites implementation.

In 2012, another program emerged in the US that grew from the WCI in California i.e., the CCTP. The design factors of the CCTP align with the prior cap and trade programs, including the main case studies. While full auctioning of allowances was envisaged at the start of the CCTP to lower compliance costs, there has been some direct (free) allocation of allowances for emission intensive sectors. In the lead up to the CCTP, California had implemented complementary policies such as energy efficiency standards, renewable energy targets and a low carbon fuel standard (Schatzki & Stavins 2012).

8.7 Limitations of the study and future directions

In both case studies, it is envisaged that over time the cap on emissions will continue to lower and allowances will become scarce as they are removed from circulation. The in-depth period of analysis for this study was carried out in the early stages of both programs, while some up to date material on both programs has been included in recent revisions of the study.

Schamalensee and Stavins (2015) have noted that emissions leakage is a problem for regional schemes like the RGGI and the Californian CCTP, given the interconnected electricity markets across the US and lack of a cohesive policy for emissions reduction. Highly emissions intensive power can be imported into the regions covered by a program for emissions reduction. A favourable price differential and interconnected electrical transmission grid also makes it possible for power with a low emissions intensity to be circulated.

The GFC lowered emissions in line with the depressed economic activity. As such, it is difficult to identify the changes in the level of emissions that are a direct result of cap and trade. The impact of the GFC may now be repeated during the COVID-19 pandemic and therein may lie an opportunity to adjust program parameters to allow for a new emissions scenario. The operation of contingency reserves and price collars on allowances may be suited to the adjustments needed during a decline in economic activity.

Among other things, the variation observed in emission trends reflects regional differences that have not been the focus of this study. The small number of programs that were operating when the study began provides limited data to address the research questions. The small size of this data sample could compromise the external validity of the results. A number of new programs have started and the study has not been able to reap the full benefit from the observation of trends in the design of other greenhouse gas emissions trading programs that have been progressing in all other regions, e.g. the US, Korea and China.

During the recent revisions of the study, it has been suggested that greenhouse gas emissions trading is based on a technologically conservative approach. There may be opportunities to embed technological innovations more deeply in the tradable permit mechanism. Section 8.8 frames the case studies in relation to innovation.

8.8 Innovation

The importance of innovation in relation to greenhouse gas mitigation is first raised in the Executive summary of this study. The relationship can be couched broadly in terms of innovation in the use of policy instruments such as the allowance reserves, funding renewables and by linking ETS to other alternative policies. Questions are raised in this study about a divergence away from the success of the US ARP, in which fuel switching, and emissions scrubbing were innovative practices.

Jordaan et al. (2017) consider that there are technology push and market pull elements to an energy technology innovation system. International cooperation on agreed emission reductions under the Kyoto Protocol set the scene; at a national level, the public sector policies and private sector investment underpin innovation. Greenhouse gas emission trading is put in place for two reasons, firstly to provide a platform for the regulation of the greenhouse gases and secondly to provide an economic imperative due to the net cost imposed on the owners of emitting facilities.

Su and Moaniba (2017) have found that a country with a large carbon footprint is more likely to commit to research and development in innovative energy technologies. In this study, the EU ETS and the RGGI have both managed to reduce emissions against a low allowance price background. Analysis has found that the RGGI reduced the first control period emissions by 18.4% and overall, in the EU ETS between 2008-2016 covered emissions dropped by 11.5% (Bayer & Aklin 2020).

The low allowance price environment has prompted several enquiries into how the cost effectiveness of the programs. In the RGGI, it was found that there was a net present value economic benefit of $1.6 billion, or $33 per capita across the region (EDF-IETA 2014). Bayer and Aklin consider that the EU ETS triggered low carbon innovation by credibly signalling a much-increased cost in the future.

In the RGGI, there is a requirement for each state to invest a minimum of 25% of the auction proceedings to consumer benefit programs such as energy efficiency, renewables, and direct bill assistance. In Phase 3, the EU ETS operated the NER 300 programme and the Innovation fund for low-carbon energy demonstration projects. Over Phase 4, at least 450 million allowances will be auctioned to fund renewables, innovations in energy intensive industry, carbon capture and storage and stored energy (EU 2019).

Alternative policies have the potential for emissions reductions outside of, or in parallel with, greenhouse gas emissions trading. However, alternative emission reduction policies can introduce processes that are not optimal in terms of cost-effectiveness. These alternative policies may be viewed as more acceptable to the community. The study finds evidence that this divergence is a characteristic of the factors that are strongly aligned to acceptance. That can facilitate acceptance of emissions trading, but in turn are inversely correlated with reductions in greenhouse gas emissions.

Ongoing research would be helpful to determine how the competing interest presented by alternative policies can be best tested.

8.9 Summary

In terms of greenhouse gas abatement through cap and trade and after decades of effort, it can been shown that despite evenly distributed popularity and unpopularity of this approach, progress has been made toward cost effective emissions trading. A paradox is apparent in Australia where, while there has been considerable effort to design programs, bipartisan agreement on a market-based mechanism has not occurred. The alternative strategies that have been enacted are widely considered to be inappropriate for achieving the required emissions reductions.

The material presented here shows that market-based programs have persisted and are starting to bear fruit in terms of significant emissions reductions. Estimates from the study indicate that in the EU ETS between 2005 and 2018, there was an overall emissions reduction that was in the order of 19.4%. These figures are supported in a study by Borghesi and Montini (2016) which indicates that the EU ETS had met its 2020 target of a 20% reduction on 1990 levels by 2013 with a 20.7% reduction.

In the study on the RGGI, an estimate for emissions reduction reveals a figure of 40.7%. Spiegel (2020) suggests that the performance of the RGGI in reducing emissions is almost twice what has been achieved across the US. Also, that revenue from the RGGI has contributed US$2.4b of revenue to the participating states.

This study has highlighted some new and some enduring design factors for greenhouse gas cap and trade policy. In Chapters 5 and 6, it is shown that the case studies have left an important legacy of information that relates to the treatment of the alignment between the factors and the focus of each program in relation to the constraints. In Section 5.6, Tables: 29 and 30 give an indication as to the important factors in the design of the EU ETS. Similarly, for the RGGI in Section 6.6, Tables: 44 and 45 indicate the important factors in the initial design.

From Section 3.4 in Table 18, the alignment of the design factors in relation to the focus of a program are shown. In Section 8.5, Table 51 shows the factors that are highly ranked within the EU ETS. The two most prominent factors are legislation and rules, indicating that the scheme is focussed on emissions reduction. Table 52 shows the factors that are highly ranked in the RGGI. The two most prominent factors are allowance allocation and coverage. This does not provide a clear indication as to what the focus of the RGGI is according to Table 18.

In Section 3.4, Table 18 shows the alignment for the various design factors, taking into consideration elements from the case main case studies, but also the literature more generally. The observations that can be made in relation to Table 18 follow.

For example, a wide coverage, i.e., the inclusion of many industrial sectors, is often combined with soft targets and a generous allocation of the initial allowances. If the targets for emissions reduction are also low, then gaining acceptance of emissions trading is easier. In this situation the ability of the programs to reduce emissions is limited.

It also became apparent that some factors can have an inverse relationship to the objective of the programs in mitigating emissions. While they can be important in terms of acceptance, this group of factors may create a barrier in achieving the desired outcomes of cost-effective emission reductions.

The alternative is a more challenging target for emissions reductions that in turn leads to a higher allowance price and increased costs of production. These increased costs provide an economic incentive for the uptake of emissions reducing activities. These characteristics also make it more difficult to gain acceptance of emissions trading. This inverse correlation between emissions reduction and the factors that are associated with acceptance, defines the policy dilemma.

The increasing impact of emissions trading to date indicates that attention is being paid to this inverse correlation. The awkward policies that were developed for the implementation of the programs distorted the market-based solution. As the programs have developed, the governing bodies have taken advantage of the flexible factors and revised the designs to achieve greenhouse gas emissions trading that is reducing emissions in line with the goals of the programs.

References

Adams, P. 2007. Impacts on the Australian economy of reducing greenhouse gas emissions. Report from the Centre of Policy Studies, Monash University. Clayton, Australia.

Akter, S., & Bennett, J. 2009. Household perceptions of climate change and preferences for mitigation action: the case of the carbon pollution reduction scheme in Australia. Crawford School of Economics and Government, Australian National University, Canberra.

Aldy, J., Barrett, S., & Stavins, R. 2003. Thirteen plus one: a comparison of global climate policy architectures. Climate Policy, vol. 3, pp. 373-397. Viewed 5 September 2016< http://belfercenter.ksg.harvard.edu/ files/.

Ash, M. 2012. Taxation, innovation and the environment. Special Report, OECD, Paris.

Aulisi, A., Farrell, A. E., Pershing, J., & Vandeverr, S. 2005. Greenhouse gas emissions trading in the US: observations and lessons from the OTC NO_x budget program. World Resources Institute, Washington D.C. Viewed 19 April 2010 < http://pdf.wri.org/nox_ghg.pdf.

Australian Bureau of Meteorology (BOM), 2018. State of the Climate 2018. Viewed 7 April 2019 <http:// http://www.bom.gov.au/state-of-the-climate/index.shtml.

Australian Department of Climate Change. 2008. Carbon pollution reduction scheme Australia's low pollution future. Viewed 30 May 2013 < http://www.climate change.gov.au/reducing.carbon/carbon.pricing/carbon.pollution.reduction.scheme %E2%80%94overview.and.design.features.

Australian Government. 2013a. Starting emissions trading on 1 July 2014. Policy summary. Viewed 1 December 2014 < http://www.climatechange.gov.au/ sites/climatechange /files/files/reducing.carbon/carbon.pricing.policy/ cef.policy.summary.moving.ets.pdf.

Australian Government. 2013b. Australian National Greenhouse Accounts, National Inventory Report 2011, Volume 1. The Australian Government Submission to the United Nations Framework Convention on Climate Change April 2013. Viewed 14 October 2016 < https://www.environment.gov.au/system/files/resources/ada8f97e-1118-4a63-87e4-285eef968879/files/ausnir2011vol1.pdf

Australian Government. 2015. Australia's Intended Nationally Determined Contribution to a new Climate Change Agreement. Viewed 15 January 2017 < http://www4.unfccc.int/submissions/INDC/Published%20Documents/Australia/1/Australias%20Intended%20Nationally%20Determined%20Contribution%20to%20a%20new%20Climate%20Change%20Agreement%20-%20August%202015.pdf.

Australian Greenhouse Office (AGO). 1999. National emissions trading: establishing the boundaries. Discussion Paper number 1. Australian Greenhouse Office, Canberra.

Australian Parliament. 2011. Securing a clean energy future: some economic aspects. Viewed 5 September 2016 <http://www.aph.gov.au/About_Parliament/ Parliamentary_Departments/ Parliamentary_Library/pubs/rp/rp1112/12rp05.

Australian Parliament. 2013. Carbon pollution reduction scheme. Viewed 2 September 2013< http://www.aph.gov.au /about.parliament/parliamentry.departments/ parliamentary .library/browse.by.topic/climatechange/governance/domestic /national/crps.

Australian Workers Union (AWU). 2009. Over the CPRS horizon: balancing the impacts of the global financial crisis with the introduction of the Carbon Pollution Reduction Scheme. Australian Workers Union Policy Position Paper. Viewed 8 June 2011< http://www.awu.net.au/over.the.cprs.horizon.pdf.

Babiker, M., Reilly, J., & Viguier, L. 2002. Is international emissions trading always beneficial? Report No. 93, MIT E40-271. Joint Program on the Science and Policy of Global Change, Cambridge, Mass.

Bailey, I., & Rupp, S. 2004. Politics, industry and the regulation of industrial greenhouse-gas emissions in the UK and Germany. European Environment, vol. 14, pp. 235-250.

Baily, M., Elliot, D. 2009. The US Financial and economic crisis: where does it stand and where do we go from here? Initiative on business and public policy at Brookings. Viewed 21 October 2016 < https://www.brookings.edu/wp-content/uploads/2016/06/0615_economic_crisis_baily_elliott.pdf

Balietti, A. 2016. Trader types and volatility of emission allowance prices. Evidence from EU ETS phase 1. Energy policy, volume 98, pp. 607-620.

Baron, R., & Colombier, M., 2005. Emissions trading under the Kyoto protocol: how far from the ideal. In Yamin, F. (ed.). Climate change and carbon markets: A handbook of emission reduction mechanisms. Earthscan, Trowbridge, UK, pp. 321-349.

Baumol, W. J., & Oates, W. E. 1988. The theory of environmental policy. 2nd ed. Cambridge University Press, Cambridge, Mass.

Bayer, P., & Alkin, M. 2020. The European Union Emissions Trading System reduced CO2 emissons despite low prices. Article in Proceedings of the National Academy of Sciences of the United States of America (PNAS), vol 117, no. 106, pp. 8804-8812.

Beder, S. 2009. The corporate agenda for environmental property rights. Faculty of Arts Papers, University of Wollongong. Viewed 27 April 2012< http://ro.uow.edu.au/ artspapers /214,

Benz, E., & Henglebrock, J. 2008. Liquidity and price discovery in the European CO_2 futures market: An intraday analysis. Viewed 26 June 2013< http://papers.ssrn. com/sol3/papers.cfm?abstract_id=1220389,

Bernard, A., Vielle, M., & Viguier, L. 2005. Carbon tax and international emissions trading: a Swiss perspective. In Haurie, A., Viguier, L., (eds.), The coupling of climate and economic dynamics. Springer, New York City, pp. 295-319.

Bernstein, L., Bosch, P., Canziani., Chen, Z., Christ, R., Davidson, O., Hare, W., Huq, S., Karoly, D.,Kattsov, V., Kundzewicz., Liu, J., Lohmann, U., Manning, M., Matsuno, T., Menne, B., Metz, B., Mirza, M., Nicholls, N., Nurse, L., Pachauri, R., Palutikof, J., Parry, M., Qin, D., Ravindranath, N., Reisinger, A., Ren, J., Riahi, K., Rosenzweig, C., Rusticucci, M., Schneider, S., Sokona, Y., Solomon, S., Stott, P., Stouffer, R., Sugiyama, T., Swart, R., Tirpak, D., Vogel, C., Yohe, G. 2007. Climate change 2007: synthesis report. Contribution of Working Groups I, II and III to the Fourth IPCC Assessment. Valencia, Spain 12-17 November.

Bernstein, S., Betsill, M., Hoffmann, M., & Paterson, M. 2010. A tale of two Copenhagen's: carbon markets and climate governance. Millennium: Journal of International Studies, vol. 39, pp. 161-173.

Betts, R., Jones, C., Knight, J., Keeling, R., Kennedy, J. 2016. El Nino and a record CO_2 rise. Nature Climate Change, vol 6, no 9, pp. 806-810.

Biermann, F., & Gupta, A. 2011. Accountability and legitimacy in earth system governance: a research framework. Ecological Economics, vol. 70, pp. 1856-1864.

Boehmer-Christiansen, S. 2003. Science, equity, and the war against carbon. Science Technology Human Values, vol. 28, pp. 69-92.

Boemare, C., & Quirion, P. 2002. Implementing greenhouse gas trading in Europe: lessons from economic literature and international experiences. Ecological Economics, vol. 43, pp. 213-230.

Bolin, B. 2006. A history of the science and politics of climate change: the role of the International Panel on Climate Change. Cambridge University Press, Cambridge, Mass.

Borghesi, S., Montini, M. 2016. The Best (and Worst) of GHG Emission Trading Systems: Comparing the EU ETS with Its Followers. Review article, Frontiers in Energy Research. Sustainable Energy Systems and Policies. Viewed 23 September 2020< www.frontiersin.org.

Breidenich, C., Magraw, D., Rowley, A., & Rubin, J. W. 1998. The Kyoto Protocol to the United Nations Framework Convention on Climate Change. The American Journal of International Law, vol. 92, pp. 315-331.

British Broadcasting Corporation (BBC). 2005. On This Day 2005: Kyoto Protocol comes into force. Viewed 26 September 2016 < http://news.bbc.co.uk/onthisday/hi/dates/stories/february/16/newsid_4930000/4930554.stm

Bureau of Meteorology (BOM). 2003. The greenhouse effect and climate change. Special report. Australian Bureau of Meteorology, Canberra. Viewed 28 April 2012 <www.bom.gov.au.

Burtraw, D., Palmer, K., Bharvirkar, R., & Paul, A. 2001. The effect of allowance allocation on the cost of carbon emission trading. Discussion Paper 01-30. Resources for the Future, Washington DC.

Burtraw, D. 2002. Markets for clean air: the U.S. acid rain program: A. Denny Ellerman, Paul L. Joskow, Richard Schmalensee, Juan-Pablo Montero, Elizabeth M. Bailey, Cambridge, UK: Cambridge University Press, 2000. Regional Science and Urban Economics, vol. 32, pp. 139-144.

Burtraw, D., Evans, D., Krupnick, A., Palmer, K., & Toth, R. 2005. Economics of pollution trading for SO_2 and NO_x. Discussion Paper. Resources for the Future, Washington DC.

Burtraw, D., Palmer, K., & Kahn, D. 2005. Allocation of CO_2 emissions allowances in the regional greenhouse gas cap-and-trade program. Discussion Paper. Resources for the Future, Washington DC.

Burtraw, D., & Szambelan, S.J. 2009. U.S. emissions trading markets for SO2 and NO_x. Discussion Paper. Resources for the Future, Washington DC.

Canadell, J., Le Quere, C., Raupach, M., Field, C., Buitenhuis, E., Ciais, P., Conway, T., Gillett, N., Houghton, R., Marland, G. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proceedings of the National Academy of Sciences of the United States of America, vol. 104, pp. 18866-18870.

California Air Resources Board (CARB). 2016. Californian climate investments: 2015 County and Legislative District List of Implemented GGRF Projects. Reported by Agencies Implementing California Climate Investments. Californian Air Resources Board. Viewed 19 July 2016< http://www.arb.ca.gov/cc/capandtrade /auction proceeds/auctionproceeds.htm.

California Air Resources Board (CARB). 2019. California & Quebec release results for 19^{th} joint cap-and-trade auction. Viewed 19^{th} June 2019< https://ww2.arb.ca.gov.

Carbon Offset Research and Education (CORE). 2011. Regional greenhouse gas initiative. Carbon Offset Research and Education, Stockholm Environment Institute, Stockholm. Viewed 7 September 2016< http://www.co2offsetresearch .org/policy /RGGI.

Carbon Pollution Reduction Scheme (CRPS). 2008. Carbon Pollution Reduction Scheme. Australia’s low pollution future white paper, commonwealth of Australia. Viewed 27 July 2015< http://pandora.nla.gov.au/pan /102841/ 20090728-0000/www.climatechange.gov.au/whitepaper /report/index.html.

Carlson, A. 2012. Designing effective climate policy: cap-and-trade and complementary policies. Harvard Journal on Legislation, vol. 49, pp. 208-248.

Caron, J., Rausch, S., & Winchester, N. 2015. Leakage from sub national climate policy: the case of California’s cap and trade program. The Energy Journal, vol. 6, pp. 167-190.

Cason, T. N., Gangadharan, L., & Duke, C. 2003. Market power in tradable emission markets: a laboratory test bed for emission trading in Port Phillip Bay, Victoria. Ecological Economics, vol. 46, pp. 469-491.

CDC Climat research Caisse Des Depots group (CDC). 2012. The EU ETS carbon price: to intervene or not to intervene? Climate Brief No. 12. CDC Climat Research. Viewed 14 August 2015< http://www.cdcclimat.com/IMG/pdf/12-02 climate brief 12 the eu ets carbon price to.intervene.or.not.to.intervene.pdf.

Chan, G., Stavins, R., Stowe, R., & Sweeney, R. 2012. The SO_2 allowance trading system and the Clean Air Act Amendments of 1990: reflections on twenty years of policy innovation. Harvard Environmental Economics Program, Cambridge, Mass.

Clemencon, R. 2008. The Bali road map: a first step on the difficult journey to a post-Kyoto protocol agreement. The Journal of Environmental Development, vol. 17, pp. 70-94.

Climate Change Authority. 2016. Policy options for Australia's electricity supply sector. Special review research report. Australian government, Climate change authority. Viewed 5 January 2017< http://climatechangeauthority.gov.au/.

Climate Change Authority. 2018. Review of the National Greenhouse and Energy Reporting legislation. Australian government, Climate change authority. Viewed 11 February 2019< https://prod-climatechangeauthority.energy.slicedtech.com.au/sites /prod.climatechangeauthority.gov.au/files/NGERS%20Final%20report%20PDF.pdf

Climate Policy Initiative (CPI). 2016. Californian carbon dashboard. Climate Policy Initiative. Viewed 5 July 2016< http://calcarbondash.org/.

Cline, W. R. 1991. Scientific basis for the greenhouse effect. The Economic Journal, vol. 101, pp. 904-919.

Coase, R. H. 1960. The problem of social cost, The Journal of Law and Economics, vol. 3, pp. 1-44.

Coers, R., & Sanders, M. 2012. The energy–GDP nexus: addressing an old question with new methods. Energy Economics, vol. 36. pp. 708-715.

Common, M., & Stagl, S. 2005. Ecological economics: an introduction. Cambridge University Press, Cambridge, Mass.

Commonwealth Scientific and Industrial Research Organisation (CSIRO). 2012. State of the climate. A joint publication of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Government Bureau of Meteorology.

Concessi, P., Hoang, T., Denée, J., & Murrell, B. 2007. Accounting for emission rights. Deloitte, Energy and Resources**.**

Convery, F. J., & Redmond, L. 2007. Market and price developments in the European Union emissions trading scheme. Review of Environmental Economics and Policy, vol. 1, pp. 88-111.

Cooper, S., Grubb, M., Rysanek, A., & Laing, T. 2011. Revenue dimensions of the EU ETS phase III (Draft). Climate Strategies, University of Cambridge, Cambridge, UK. Viewed 29 May 2013< www.climatestrategies.org.

Creswell, J. W. 2014. Research design: qualitative, quantitative, and mixed methods approaches. Fourth edition, Sage publications, Thousand Oaks, California.

Cullenward, D. 2014. How California's carbon market actually works. Bulletin of atomic scientists. vol. 70, no. 5, pp. 35-44.

Department of the Environment and Energy (DEE). 2015. Quarterly update of Australia's National Greenhouse Gas Inventory: June 2015. Department of the Environment and Energy, Canberra. Viewed 2 February 2016< https://www. environment.gov.au/climate-change/greenhouse-gas-measurement/publications.

Department for Environment, Food, and Rural Affairs (DEFRA). 2003. Commentary on preliminary 1st year results and 2002 transaction log. (Only available upon request) Viewed 22 April 2009< ttp://www.defra.gov.uk/environment/ climate change/trading/index.

Department of Environment, Land, Water and Planning (DELWP). 2019. Victoria’s renewable energy targets. Viewed 22 December 2020< https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets

Directorate General for Climate Action (EU) (DG CLIMA). 2015. Mission statement. Viewed 14 August 2015< http://ec.europa.eu/clima/about-us/mission/index_en.

Den Elzen, M.G.J., & de Moor, A.P.G. 2002. Analyzing the Kyoto protocol under the Marrakesh accords: economic efficiency and environmental effectiveness. Ecological economics, 43, pp. 141-158.

DeSerpa, A. 1993. Pigou and Coase in retrospect, Cambridge journal of economics, 1993, 17, pp. 27-50.

Ekins, P., & Baker, T. 2001. Carbon taxes and carbon emissions trading, Journal of economic surveys, vol. 15, no. 3. pp. 325-376.

Ellerman, D. 2003. Tradable permits - a market-based allocation system for the environment. vol. 4, No. 1 pp3-7. Institute for economic research, CESifo forum, Munich, Germany. Viewed 17 May 2013< http://www.cesifo-group.de/ifoHome /publications/docbase/details.html?docId=14562634.

Ellerman, D. 2005. A note on tradable permits. Environmental and Resource Economics, 31 (2005), pp.123-131.

Ellerman, D. 2008. The EU’s emissions trading scheme: A proto-type global system? Centre for Energy and Environment Policy Research. Viewed 9 September 2016 < http://belfercenter.ksg.harvard.edu/publication/18488/eu_emission_trading_scheme.

Ellerman, D., Joskow, P., & Harrison, D. 2003. Emissions trading in the U.S. experience, lessons, and considerations for greenhouse gases. Policy paper, Pew Centre on Global Climate Change, Arlington VA.

Ellerman, D., Parsons, J., Feilhauer, S. 2008. The puzzling SO_2 price spike of 2005-2006. MIT Centre for Energy and Environment policy research (CEEPR). Viewed 23 October 2016 < http://www.mit.edu/~jparsons/Presentations/SO2%20May%2008.pdf.

Ellerman, D. A., Webster, M. D., Parsons, J., Jacoby, H. D., & McGuiness, M. 2008. Cap-and-Trade: Contributions to the Design of a U.S. Greenhouse Gas Program, Cambridge, MA: MIT Centre for Energy and Environmental Policy Research, pp. 2-35.

Ellerman, D. A., Joskow, P. L., Schamalensee, R., Montero, J. P., & Bailey, E. M. 2000. Markets for clean air: The U.S. acid rain program. Cambridge University Press. Cambridge U.K.

Ellis, J., Tirpak, D. 2006. Linking GHG emission trading schemes and markets. Viewed 12 September 2016 < http://www.oecd.org/env/cc/37672298.pdf.

Emissions-EU ETS.com. 2019. Webpage. Viewed 7 February 2019< https://www. emissions-euets.com/carbon-market-glossary/878-phases-trading-periods-eu-ets

Energy NSW. New South Wales Government, Department of Planning, Industry and Environment. 2020. Net Zero Emissions Plan, Stage 1: 2020-2030. Viewed 22 December 2020< https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/net-zero-plan-2020-2030-200057.pdf

Engels, A., Knoll, L., Huth, M. 2008. Preparing for the ‘real’ market: National patterns of institutional learning and company behaviour in the European emissions trading scheme (EU ETS), European Environment, 18, pp. 276–297.

Environment Northeast (ENE). 2011. Environment northeast, RGGI emissions trends report. Viewed 9 September 2016< http://www.usclimatenetwork.org/resource-database/ENE.pdf

Europa. 2008. Questions and answers on the commission's proposal to revise the EU emissions trading system. Viewed 5 May 2012< http://europa.eu/rapid/press ReleasesAction.do?reference=MEMO/08/35.

Europa. 2012. Communication from the commission to the European parliament and the council. Towards an enhanced market oversight framework for the EU emissions trading scheme. Viewed 9 September 2016< http://ec.europa.eu/danmark/ documents / alle_emner/miljo/101221_emissions-rapport_en.pdf

Europa. 2015. EU ETS handbook. Viewed 21 October 2016. < http://ec.europa.eu/clima/publications/docs/ets_handbook_en.pdf

Europa. 2016. European commission climate action. Viewed 5 July 2016< http:// ec.europa.eu/clima/ policies/ets/ faq _en.

European Environment Agency (EEA), (2016) Eionet GEMET Thesaurus, concepts list for environmental policy. Viewed 23 October 2016 < http://www.eionet.europa.eu/gemet/theme_concepts?letter=20&th=11&langcode=en&ns=4.

European Commission. 2016a. Paris agreement. Key points. Viewed 2 November 2016 < https://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm.

European Commission. 2016b. A policy framework for climate and energy in the period from 2020 up to 2030. Viewed 21 October 2016. < http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014SC0015&rid=3.

European Commission. 2020. Report from the Commission to the European Parliament and the Council. Viewed 20 August 2020. <http:// eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX :52019D 0557(01).

European Commission Green Paper. 2000. Green paper on greenhouse gas emissions trading within the European Union. Viewed 9 September 2016< http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52000DC0087 &from=EN.

European Parliament. 2016. Establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. Viewed < http://eur-lex.europa.eu/legal-content/EN/ TXT/PDF/?uri=CELEX: 32003 L0087&rid=2.

Federal Office of Environment (FOEN). 2009. Switzerland’s Fifth National Communication under the UNFCCC, Bern. Viewed < https://unfccc.int/resource/ docs/natc/che_nc5.pdf 10 April 2019.

Fisher, B. S., Nakicenovic, N., Alfsen, K., (contributing lead authors). 2007: Chapter 3, Issues related to mitigation in the long term context, In Climate change 2007: mitigation. Contribution of working group III to the fourth assessment report of the inter-governmental panel on climate change [Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., & Meyer, L.A. (eds.)], Cambridge University Press, Cambridge.

Flachsland, C., Edenhofer, O., Jakob, M., & Steckel, J. 2008. Developing the international carbon market. Linking options for the EU ETS report to the policy planning staff in the Federal foreign office. Potsdam institute for climate impact research, Potsdam Germany.

Fornaro, M., Winkelman, K., & Goldstein, D. 2009. Accounting for emissions: emerging issues and the need for global accounting standards, Journal of accountancy, July, pp. 40-45.

Frontier Economics. 2009. The economic impact of the CPRS and modifications to the CPRS. Report for the coalition and Senator Xenophon. Viewed 5 January 2017<http://share.liberal.org.au/_docs/FrontierEconomicsCPRS_Report.

Gable, G. 1994. Integrating case study and survey research methods: an example in information systems. European journal of information systems 3(2), pp. 112-126.

Garnaut, R. 2008. The Garnaut climate change review: Chapter 14. An Australian emissions trading scheme. Viewed 5 May 2012< http://www.garnautreview. org.au/chp14.htm#14_2.

Garnaut, R. 2008a. Emissions trading scheme discussion paper, Garnaut climate change review, Interim report to the Commonwealth, State and Territory Governments of Australia.

Garnaut, R. 2008b. Garnaut climate change review draft report June 2008, Viewed 5 July 2008< http://www.garnautreview.org.au/CA25734E0016A131/pages/about.

Garnaut, R. 2014. China’s energy transition: effects on global climate and sustainable development, MSSI public lecture series paper No. 1, Melbourne Sustainable Society Institute, the University of Melbourne.

Godby, R., Mestelman, S., Muller, A., & Welland, D. 1998. An experimental economic analysis of emissions trading with shares and coupons in the presence of market uncertainty, Environmetrics, vol. 9, pp. 67-79.

Goulder, L. 2013. Markets for pollution allowances: what are the (new) lessons? Journal of economic perspectives. vol. 27, no. 1. Winter 2013, pp. 87–102.

Green, R. 2007.Carbon tax or carbon permits: the impact on generators’ risks. Institute for Energy Research and Policy, University of Birmingham.

Grubb, M. 1989. The greenhouse effect: negotiating targets. London, Royal Institute of International Affairs, Energy and Environmental Programme.

Grubb, M. 1990. The greenhouse effect: negotiating targets. International affairs (Royal institute of international affairs 1944), vol. 66, no. 1(Jan, 1990), pp.67-89.

Grubb, M. 2000. Economic dimensions of technological and global responses to the Kyoto protocol, Journal of economic studies, vol. 27, no. 1/2, pp. 111-125.

Grubb, M. 2011. Durban: the darkest hour? Climate Policy, vol. 11, no. 6, pp. 1269-1271.

Grubb, M., & Yamin, F. 2001. Climatic collapse at The Hague: what happened, why, and where do we go from here? International affairs (Royal institute of international affairs 1944), vol. 77, no. 2, pp. 261-276.

Hahn, R. W. 1984. Market power and transferable property rights. Quarterly journal of economics, vol. 99, no. 4, pp. 753-765.

Hahn, R. W., & Hester, G. 1989. Marketable permits; lessons for theory and practice, Ecology law quarterly. Viewed 12 June 2008< www.heinonline.org.

Hahn, R., & Stavins, R. 1999. What has Kyoto wrought? The real architecture of international tradable permit markets, Research paper [draft], John F Kennedy School of Government, Harvard University.

Haites, E. 2005. Conclusion: Mechanisms, linkages and direction of the future climate regime, in Yamin, F. (ed.) 2005. Climate change and carbon markets: A Handbook of Emission Reduction Mechanisms, Earthscan, Cromwell Press Ltd, Trowbridge, UK, pp. 321-349.

Haites, E., Maosheng, D., Gallagher, K. S, Mascher, S., Narassimhan, E., Richards, K. R., Wakabayashi, M. 2018. Experience with Carbon Taxes and Greenhouse Gas Emissions Trading Systems. Viewed 26 January 2019< https://www.researchgate. net/publication/323459672. Experience with Carbon Taxes and Greenhouse Gas Emissions Trading Systems.

Hansjurgens, B. 2011. Markets for SO_2 and NO_x – what can we learn for carbon trading? Focus article in WIREs Climate Change, vol. 2, pp. 635-646.

Harrison, D. Jr., Klevnas, P., Radov, D., & Foss, A. 2007. Complexities of allocation choices in a greenhouse gas emissions trading program, International Emissions Trading Association, National Economic Research Associates (NERA) Economic Consulting. Boston USA.

Harrison, D. Jr., & Radov, D. B. 2002. Evaluation of alternative initial allocation mechanisms in a European Union greenhouse gas emissions allowance trading scheme, National Economic Research Associates (NERA) Economic Consulting, Boston USA. Prepared for DG Environment European Commission. Brussels, Belgium.

Harrington, W., Morgenstern, R. D., & Sterner, T. (eds). 2004. Choosing environmental policy: comparing instruments and outcomes in the United States and Europe, Resources for the future, Washington DC.

Helm, D., & Pearce, D. 1991. Introduction, in Helm, D. (ed.).1991. An overview: Economic policy towards the environment, Oxford Review of Economic Policy, Blackwell publishers, Oxford, pp. 1-24.

Hemming, D. 2005. Emissions trading scheme for the NSW electricity sector: rationale, implementation and experience to date. NSW Department of Energy, Utilities and Sustainability. Thorton, Australia.

Hibbard, P., & Tierney, S. 2011. Carbon control and the economy: economic impacts of RGGI's first three years, The Electricity Journal, vol. 24, issue 10, pp. 30-40.

Hibbard, P., Tierney, S., Okie, A., & Darling, P. 2011. The economic impacts of the Regional Greenhouse Gas Initiative on ten northeast and Mid-Atlantic States. Review of the use of RGGI auction proceeds from the first three-year compliance period. Analysis group. Boston, Massachusetts.

Hintermann, B. 2010. Allowance price drivers in the first phase of the EU ETS. Journal of Environmental Economics and Management. No. 59, pp. 43-56.

Höhne, N., & Blok, K. 2005. Calculating historical contributions to climate change - discussing the 'Brazilian proposal', Climatic Change, vol. 71, no. 1, pp. 141-173.

Holdren, J. P., 1991. Population and the Energy Problem. Population and Environment: A Journal of Interdisciplinary Studies. vol. 12, no. 3, pp. 231-255.

Holland, M. 2011. Climate disaster, Herald Sun newspaper, Melbourne, Australia. 23 May 2011, p.4.

Holt, C., Shobe, W., Burtraw, D., Palmer, K., & Goeree, J. 2007. Auction design for selling CO_2 emission allowances under the Regional greenhouse gas initiative. Viewed 9 March 2013< http://www.rff.org/ News/ Features /Pages /Auction_Design_RGGI.aspx.

Hood, C. 2013. Managing interactions between carbon pricing and existing energy policies (Report). Paris: IEA Insights Publication.

Hovenkamp, H. 2009. The Coase theorem and Arthur Cecil Pigou, Arizona Law Review, vol. 51, p. 633.

Howe, W. 2007. Australia's climate change regime (an alternative approach to climate change). Working paper, Macquarie University – Division of law. Sydney, Australia.

Intergovernmental Panel on Climate Change (IPCC). 2016. Report of the Intergovernmental Panel on Climate Change. Viewed 27 July 2016< https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf.

International Carbon Action Partnership (ICAPa). 2019. (Webpage) Emissions trading worldwide. The State of Play of cap and trade in 2018. Viewed 23 January 2019< https://icapcarbonaction.com/en/?option=com_attach&task=download&id=597.

International Carbon Action Partnership (ICAPb). 2019. (Webpage) ETS detailed information. USA – Regional Greenhouse Gas Initiative (RGGI). Viewed 11 June 2019< https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format= pdf&layout= list &systems []=50.

International Emissions Trading Association (IETA). 2015. (Webpage) Overlapping policies with the EU ETS. Viewed 11 June 2019< https://www.ieta.org/resources/ EU/IETA _ overlapping _policies_ with_the_EU _ETA.pdf.

International Financial Reporting Standards (IFRS). 2013. International Financial Reporting Standards foundation project update. IASB announces membership of consultative group for rate regulation. Viewed 17 July 2013< http://www.ifrs .org/ Alerts/Project Update/Pages/ aspx.

Independent Pricing and Regulatory Tribunal (IPART). 2013. Report from the Independent Pricing and Regulatory Tribunal of New South Wales. NSW greenhouse reduction scheme. Strengths, weaknesses and lessons learned. Viewed 19 August 2015< http:// www.ipart.nsw.gov.au/.

Ishikida, T., Ledyard, J., Olsen, M., & Porter, D. 2000. Experimental test bedding of a pollution trading system: southern California's RECLAIM emissions market. Division of the Humanities and Social Sciences, California Institute of Technology, Pasadena.

Jacobs Group (Australia). 2016. Australia's climate policy options. Modelling of alternate policy scenarios. A report for Energy Networks Australia. Viewed 5 January 2017< http://www.energynetworks.com.au/sites/default/files/australias_climate_policy_options_modelling_of_alternate_policy_scenarios_22082016.

Janissen, B. 2000. Design issues for a National greenhouse gas trading system: an Australian perspective, RECIEL 9 (3), Blackwell, Oxford UK, Malden MA, USA.

Jiang, K. 2014. China's CO_2 Emission scenario toward 2 degree global target, presentation to Victoria University conference 'abrupt change in China's energy path: implications for China, Australia and the global climate'. Viewed 5 September 2014< http://www.vu.edu.au/sites/default/files/cses/pdfs/Kejun.2014. China's. CO2.emission.scenario.pdf.

Jordaan, S, M., Romo-Rabago, E., McLeary, R., Reidy, L., Nazari, J., Herremans, I, M. 2017. The role of energy technology innovation in reducing greenhouse gas emissions: A case study of Canada. Renewable and Sustainable Energy Reviews, 78 (Elsevier 2017), pp. 1397-1409.

Joskow, P. L., Schmalensee, R., & Bailey, E. M. 1998. The market for sulphur dioxide emissions: The American Economic Review, vol. 88, no. 4, pp. 669-685.

Johnston, A. 2006. Free allocation of allowances under the EU emissions trading scheme: legal issues, Climate Policy, vol. 6, pp. 115–136.

Jotzo, F. 2006. Global climate policy after the Kyoto protocol flexible economic mechanisms for south and north under uncertainty and institutional constraints. A thesis submitted for the degree of Doctor of philosophy of the Australian National University.

Jotzo, F., & Pezzey, J. 2007. Optimal intensity targets for greenhouse gas emissions trading under uncertainty. Environmental and Resource Economics, vol. 38, pp. 259-284.

Kander, A., Malanima, P., & Ward, P. 2013. Power to the people. Energy in Europe over the last five centuries, Princeton University Press, Princeton, New Jersey.

Konidari, P., & Mavrakis, D. 2007. A multi-criteria evaluation method for climate change mitigation policy instruments, Energy Policy, vol. 35, pp. 6235-6257.

Kosobud, R. F., Stokes, H. H., & Tallarico, C. D. 2002. Tradable environmental pollution credits: a new financial asset, University of Illinois at Chicago. Review of Accounting and Finance, vol. 1, no. 4, pp. 68-88.

Kaya, Y., Yokobori, K. 1997. Environment, energy, and economy: Strategies for sustainability. United Nations University Press. Shibuya-ku, Tokyo, Japan.

Laing, T., Sato, M., Grubb, M., & Comberti, C. 2013. Assessing the effectiveness of the EU emissions trading system. Centre for climate change economics and policy, working paper 126. Grantham research institute on climate change and the environment, working paper 106. Viewed 10 August 2015< http://www.lse.ac.uk/GranthamInstitute/wp.content/uploads/2014/02/WP106.effectiveness.eu.emissions-trading-system.pdf.

Lefevere, J. The EU Greenhouse Gas Emission Allowance Trading Scheme in Yamin, F. (ed.). 2005. Climate change and carbon markets: A handbook of emission reduction mechanisms, Earthscan, Cromwell Press Ltd, Trowbridge, UK, pp. 321-349.

Lejano R.P., & Hirose, R. 2007. Testing the assumptions behind emissions trading in non-market goods: the RECLAIM program in southern California, Environmental Science & Policy, Vol. 8, pp. 367-377.

Le Quere, C., Jackson, R.B., Jones, M.W., Smith, A.J.P., Abernathy, S., Andrew, R.M., De-Gol, A.J., Willis, D.R., Shan, Y., Canadell, J.G., Friedlingstein, P., Creutzig, F., Peters, G.P. 2020. Temporary reduction in global co2 emissions during the COVID 19 forced confinement. Article in Nature Climate Change, vol 10, July 2020, pp. 647-653.

Luken, R., Grof, T. 2006. The Montreal protocol's multilateral and sustainable development, Ecological Economics, vol. 56, issue 2, pp. 241-255.

Mansanet-Bataller, M., Chevallier, J., Hervé-Mignucci, M., & Alberola, E. 2010. The EUA-sCER spread: compliance strategies and arbitrage in the European carbon market. Mission Climate Working Paper, Paris, France.

Mazengarb, M. 2020. Canberra is a model for using climate action to drive recovery, minister says. Article in Renew Economy. Viewed 22 December 2020< https://reneweconomy.com.au/canberra-is-a-model-for-using-climate-action-to-drive-economic-recovery-minister-says-27075/

Mathesius, S., Hofmann, M., Caldeira, K., Schellnhuber, H. 2015. Long-term response of oceans to CO_2 removal from the atmosphere. Nature Climate Change, vol 5, no 12, pp. 1107-1113.

McKibbin, W. J., Morris, A., & Wilcoxen P. J. 2009. A Copenhagen collar: achieving comparable effort through carbon price agreements, paper. Recommendations from the 2009 Brookings Blum roundtable, Brookings Institute, Washington D.C.

McKibbin, W. J., Ross, M. T., Shackleton, R., & Wilcoxen, P. J. 1999. Emissions trading, capital flows and the Kyoto protocol. (Economics and Environment Network Working Papers 9901). Australian National University, Economics and Environment Network.

McKibbin, W. J., Shackleton, R., & Wilcoxen, P. J. 1999. What to expect from an international system of tradable permits for carbon emissions. Resource and Energy Economics, vol. 21, issues 3-4, August 1999, pp. 319-346.

McKibbin, W. P., & Wilcoxen, P. J. 1997. A better way to slow global climate change, Brookings Policy brief No. 17, June, The Brookings institution, Washington DC.

McKibbin, W. J., & Wilcoxen, P. J. 2002. The role of economics in climate change policy, Journal of Economic Perspectives, vol. 16, no. 2. pp. 107-129.

McKitrick, R. 1999. A derivation of the marginal abatement cost curve. Journal of Environmental Economics and Management, vol. 37, pp. 306-314.

McKitrick, R. 2011. Economic analysis of environmental policy. University of Toronto Press. Toronto, Canada.

McKitrick, R., & Collinge, R. A. 2000. Linear Pigovian taxes and the optimal size of a polluting industry. The Canadian Journal of Economics / Revue Canadienne d'Economique, vol. 33, no. 4, pp. 1106-1119.

McLennan Magasanik Associates. 2009. Baseline and credit versus cap and trade emissions trading. Policy brief. Viewed 8 January 2017 < http://www.climateinstitute.org.au/verve/_resources/cap_and_trade_vs_baseline_briefing_paper_june_25_2009.

Meinshausen, M., Jeffery, L., Guetschow, J., Robiou du Pont, Y., Rogelj, J., Schaeffer, M., Hohne, N., den Elzen, M., Oberthur, S., Meinshausen, N. 2015. National post-2020 greenhouse gas targets and diversity-aware leadership. Nature Climate Change, vol 5 no 12, pp. 1098-1106.

Metz, B., & Davidson, O. R. 2001. Co-chairs IPCC working group III on mitigation of climate change, summary for policy makers, climate change 2001: mitigation, a report of working group III of the intergovernmental panel on climate change, held at Accra, Ghana. Cambridge University press, Cambridge, UK.

Metz, B., Davidson, O. R., Bosch, P. R., Dave, R., & Meyer, L. A. (eds). 2007. [IPCC]: Climate change 2007: Mitigation. Contribution of working Group III to the fourth assessment report of the intergovernmental panel on climate change [B], Cambridge University Press, Cambridge, UK and New York, USA.

Miles, K. 2010. Arbitrating climate change: regulatory regimes and investor-state disputes. Climate Law, vol. 1. pp. 63–92.

Molnar, J., & Kubiszewski, I. 2012. Managing natural wealth: research and implementation of ecosystem services in the United States and Canada. Ecosystem Services, vol. 2, pp. 44-55.

Montero, J. P., & Ellerman, D. A. 1998. Explaining low sulphur dioxide allowance prices: The effect of expectation errors and irreversibility. Paper presented at the 1998 World Congress of Environmental and Resource Economists in Venice.

Montgomery, D. 1972. Markets in licenses and efficient pollution control programs, Journal of Economic Theory, vol. 5, pp. 395-418.

Mora, M. 2010. Qualitative vs. quantitative research, when to use which. Viewed 9 August 2013< http://www.surveygizmo.com/survey-blog/quantitative-qualitative-research.

Murray, B. C., & Maniloff, P. T. 2015. Why have greenhouse gas emissions in the RGGI states declined? An econometric attribution to economic, energy market and policy factors. Energy Economics. Vol 51, pp. 581-589.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K.Griibler, A, Jung, T. Y., Kram, T., La Rovere, E. L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H. H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N., Dadi, Z. 2000. Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Napolitano, S., Schreifels, J., Stevens, G., Witt, M., La Count, M., Forte, R., Smith, K. 2007. The US acid rain program: key insights from the design, operation and assessment of a cap-and-trade program. The Electricity Journal, vol. 20, issue 7, pp. 47-58.

Narassimhan, E., Gallagher, K. S., Koester, S., Alejo, J. R. 2018. Carbon pricing in practice: a review of existing emissions trading systems. Climate Policy. vol 18, issue 8, pp. 7-8.

National Emissions Trading Taskforce (NETT). 2007. Possible design for a national greenhouse gas emissions trading scheme: final framework report on scheme design, (prepared for ongoing consideration by the Garnaut climate change review). Viewed 12 September 2016 < http://www.caf.gov.au/Documents/nett-final-report.pdf

National Oceanic and Atmospheric Administration (NOAA). 2011. National Oceanic and Atmospheric Administration study: slowing climate change by targeting gases other than carbon dioxide. Viewed 30 May 2013 < http://www.noaanews.noaa.gov /stories 2011/ 20110803 _nonco2.

National Oceanic and Atmospheric Administration (NOAA). 2013. Carbon dioxide at NOAA's Mauna Loa observatory reaches new milestone: Tops 400 ppm. NOAA. United States Department of Commerce. Viewed 23 May 2013< http//:researchmatters.noaa.gov/news.

National Oceanic and Atmospheric Administration (NOAA). 2016. Trends in atmospheric CO_2. Up to date weekly average CO_2 at Mauna Loa. Viewed 1 November 2016 < http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html.

Naughton, M. C. 1994. Establishing interstate markets for emissions trading of ozone precursors: the case of the northeast ozone transport commission and the northeast states for coordinated air use management emissions trading proposals, New York University Environmental Law Journal. Viewed 12 June 2008< http://www.law.nyu.edu/JOURNALS/ENVTLLAW/issues/vol3/1/3nyuelj195.

Newell, R., Pizer, W., Raimi, D. 2013. Carbon markets 15 years after Kyoto: lessons learned, new challenges Journal of Economic Perspectives, vol. 27, no. 1, winter 2013, pp. 123–146.

Noll, R. 1982. Implementing marketable emissions permits, American Economic Review, vol. 72, no. 2, Papers and Proceedings of the Ninety-Fourth Annual Meeting of the American Economic Association, pp. 120-124.

Nolles, K. 2007. Using markets to implement energy and environmental policy. Considerations of the regulatory challenges and lessons, learned from the Australian experience and laboratory investigation using experimental economics. A thesis submitted for the degree of Doctor of philosophy. The University of New South Wales, School of Electrical Engineering and Telecommunications.

Nordhaus, W. 1991. To slow or not to slow: the economics of the greenhouse effect, The Economic Journal, vol. 101, no. 407. pp. 920-937.

Nordhaus, W. 1993, Reflections on the economics of climate change. The Journal of Economic Perspectives. vol. 7, no.4. pp. 11-25.

Nye, M., & Owens, S. 2008. Creating the UK emission trading scheme: motives and symbolic politics, European Environment, 18, pp. 1-15.

Office of Administrative Law (OAL). 2016. California code of regulations. Regulation for the California cap on greenhouse gas emissions and market-based compliance mechanisms. Viewed < http://www.oal.ca.gov/CCR.htm on 3 July 2016.

Oikonomou, V., & Jepma, C. J. 2008. A framework on interactions of climate and energy policy instruments. Mitigation and Adaptation Strategies for Global Change, vol. 13, pp. 131–156.

O'Leary, Z. 2004. The Essential Guide to Doing Research, Sage Publications, London.

Olivier, J. G. J., Bouwman, A. F., van der Maas, C. W. M., Berdowski, J M., Veldt, C., Bloos, J P J., Visschedijk, I J H., Zandveld, P Y J., Haverlag, J L. 1996. Description of EDGAR version 2: A set of global emission inventories of greenhouse gases and ozone depleting substances for all anthropogenic and most natural sources on a per country basis and on 1^0 x 1^0 grid, A study commissioned by the Directorate-General for Environment, Air and Energy, of the Dutch Ministry of Housing, Spatial Planning and the Environment, project number 481507.

Oliver, J. G. J., Janssens-Maenhout, G., Muntean, M., & Peters, J. 2013. Trends in global CO_2 emissions; Joint report. Produced by PBL Netherlands Environmental Assessment Agency, The Hague & the European Commission Joint Research Centre, Ispra, Italy.

Outhred, H. 2004. Emission Reduction Schemes: Mandatory Renewable Energy Target (MRET), NSW Greenhouse Gas Abatement Certificates, Queensland Gas Scheme and Emission Taxes and Trading. Queensland Power and Gas Conference, 23-24 February, 2004.

Pace Energy and Climate Centre (PACE). 2011. Analysis of surplus emission allowances in the RGGI and state control of the surplus. Policy brief. Viewed 18 Feb 2013< http://www.law. pace.edu/school.of.law/sites/pace.edu.school.of.law /files /PECC/RGGI.Policy.brief. pdf.

Palmer, K., Burtraw, D., & Paul, A. 2009. Allowance allocations in a CO_2 emissions cap-and-trade program for the electricity sector in California. Resources for the future discussion paper.

Pandey, C. L. 2014. The limits of climate change agreements: from past to present. International Journal of Climate Change Strategies and Management, vol. 6, no. 4, pp. 376-390.

Parkinson, M. 2010. Why economists need to engage in the CPRS debate. An extract: 2010 Sir Leslie Melville Lecture, ANU, Canberra.

Parliament of the Commonwealth of Australia. 2009. Report 100: Treaties tabled on 25 June 2008 (2), Kyoto Protocol to the United Nations Framework Convention on Climate Change. Commonwealth of Australia, Canberra. Viewed 29 July 2016< http://www.aph.gov.au/parliamentary_business/committees/house_of_representatives_committees?url =jsct/25june2008/report2/front.pdf.

Passey, R., MacGill, I., & Outhred, H. 2008. The governance challenge for implementing effective market-based climate policies: A case study of The New South Wales Greenhouse Gas Reduction Scheme. Energy Policy 36, pp. 3009–3018.

Paterson, M., Grubb, M. 1992. The international politics of climate change, International Affairs, Royal Institute of International Affairs, vol. 68, no. 2, pp. 293-310.

Pearce, D. 1991. The role of carbon taxes in adjusting to global warming, The Economic Journal, vol. 101, no. 407, pp. 938-948.

Pearce, D. 2003. The social cost of carbon and its policy implications. Oxford Review of Economic Policy, vol. 19, no. 3.

Pearse, R. 2010. Making a Market? Contestation and climate change. The Journal of Australian Political Economy, no. 66, Dec 2010, pp. 166-198.

Pezzey, J. C. V. 2003. Emission taxes and tradable permits, a comparison of views on long-run efficiency, Environmental and Resource Economics, vol. 26, pp. 329-342.

Pezzey, J. C. V. 2006. Neither the rock nor the hard place: using payment thresholds to balance the politics and the economics of emissions control. Centre for resource and environmental studies Australian National University, Canberra, Australia.

Pezzey, J. C. V., Mazouz, S., & Jotzo, F. 2010. The logic of collective action and Australia's climate policy. The Australian Journal of Agricultural and Resource Economics, vol 54, no 2, pp. 185-202.

Plumb, M., & Davis, K. 2010. Developments in utilities prices. Reserve Bank of Australia Bulletin, December quarter, 2010.

Prime Ministerial Task Group on Emissions Trading. 1999. Australian Greenhouse Office (AGO). National emissions trading: discussion papers 1 to 4. Australian government, Canberra. Viewed 4 January 2009 < ‹http://www.greenhouse.gov.au/ emissionstrading/papers/.

Productivity Commission. 2008. What role for policies to supplement emissions trading scheme? Productivity Commission submission to the Garnaut Climate Change review. Viewed 13 September 2016 < http://www.garnautreview.org.au CA25734E0016A131/WebObj/ProductivityCommission/$File/Productivity%20Commission.pdf.

Radov, D., & Klevnas, P. 2004. Review of the first and second years of the UK emissions trading scheme. A report prepared by Nera Economic Consulting. Viewed 13 September 2015< http://webarchive.nationalarchives.gov.uk /20090908171815 /http:/www.defra.gov.uk/environment/climatechange/trading /uk/pdf/nera-commissionreport.pdf.

Regional Greenhouse Gas Initiative (RGGI). 2007. Regional greenhouse gas initiative model rule 1/5/07 final with corrections. Page 1 of 163 CO_2 budget trading program. www.rggi.org. Viewed 18 February 2013< www.rggi.org.

Regional Greenhouse Gas Initiative (RGGI). 2011. CO_2 Auctions. Viewed 14 August 2011 < https://rggi.org/market/co2_auctions.

Regional Greenhouse Gas Initiative (RGGI). 2012. Regional investment of RGGI CO_2 allowance proceeds, 2011. Viewed 4 November 2012 < www.rggi.org/rggi.

Regional Greenhouse Gas Initiative (RGGI). 2013a. Vermont CO2 budget trading program Viewed 8 February 2013< http://www.anr.state.vt.us/air/docs/ RGGI%20 Adopted%20Rule%20Text5.30.08.pdf.

Regional Greenhouse Gas Initiative (RGGI). 2013b. Market monitor reports. Viewed 28 June 2013 < http://www.rggi.org/market/market_monitor.

Regional Greenhouse Gas Initiative (RGGI). 2016. Regional greenhouse gas initiative. Auction results. Viewed 5 July 2016 < http://rggi.org/ market/co2_auctions/results.

Reinaud, J., & Philibert, C. 2007. Emissions trading: trends and prospects, OECD, IEA, Paris, France.

Robinson, J., Barton, J., Dodwell, C., Heydon, M., Milton, L. 2007. Climate change law: emissions trading in the EU and the UK. Cameron May publishers, London.

Runge-Metzger, A. 2011. Aviation and emissions trading. ICAO council briefing. Viewed 5 May 2012 < http://ec.europa.eu/clima/policies/transport/aviation/docs/ presentation.icao.en.pdf.

Saeverud, I. A., & Wettestad, J. 2006. Norway and emissions trading: from global front-runner to EU follower, International Environmental Agreements: Politics, Law and Economics. vol. 6, no. 1, pp. 91-108.

Sandu, S. 2007. Assessment of carbon tax policy as a policy for reducing carbon dioxide emissions in Australia. Dissertation submitted to the Faculty of Engineering, University of Technology Sydney.

Sandu, S., & Sharma, D. 2010. Alternative approaches to designing climate policy response: an Australian case study. Paper for the 18th International Input-Output Conference, 20-25 June 2010, Sydney, Australia.

Sathiendrakumar, R. 2003, Greenhouse emission reduction and sustainable development, International Journal of Social Economics, vol. 30, no. 12, pp. 1233-1248.

Schatzki, T., Stavins, R. 2012. Implications for policy interactions for California's climate policy. Analysis group. Viewed 19 July 2016 < http://www.analysis group.com/uploadedfiles/content/insights/publishing/ implications_policy_interactions_california_climate_policy.pdf.

Schleussner, C,-F., Rogelj, J., Schaeffer, M., Lissner, T., Licker, R., Fischer, E., Knutti, R., Levermann, A., Frieler, K., Hare, W. 2016. Science and policy characteristics of the Paris Agreement temperature goal. Nature Climate Change, vol 6, no 9, pp. 827-835.

Schmalensee, R., & Stavins, R., 2013. The SO_2 allowance trading system: the ironic history of a grand policy experiment. Journal of Economic Perspectives, vol. 27, no. 1, winter 2013, pp. 103–122.

Schmalensee, R., & Stavins, R., 2015. Lessons Learned from Three Decades of Experience with Cap and Trade, Resources for the Future - Discussion Paper. Prepared for the Review of Environmental Economics and Policy.

Schneider, S. 1990. Global warming are we entering the greenhouse century? Vintage Books, New York.

Schneider, F., & Wagner, A. 2003. Tradable permits – ten key design issues. vol. 4, no. 1, pp.15-22. Ifo Institute for Economic Research, CESifo forum, Munich, Germany. Viewed 17 May 2013 < http://www.cesifo-group.de/ifoHome/publications/docbase/ details.html?docId=14562634.

Schott, K., Savage, C., Pierce, J., Zibelman, A., Conboy, P. 2017. Energy Security Board Advice on retailer reliability, emissions guarantee and affordability. Viewed 21 May 2019< http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/ publications/documents/Energy%20Security%20Board%20ADVICE....pdf.

Scripps Research Institute. 2013. Scripps Institution of Oceanography. Scripps CO_2 data: Mauna Loa observatory. Viewed 22 July 2013< http://co2now.org/Current. CO2/CO2.Now/scripps.co2.data.mauna.loa.observatory.

Shakil, M.H., Munim, Z.H., Tasina, M., Sarwar, S. 2020. COVID 19 and the environment: Acritical review and research adgenda. Science of the Total Environent, 745 (Elsevier, 2020).

Shergold, P. 2007. Report of the task group on emissions trading, Australian Government, Prime Ministerial Task Group on Emissions Trading, Barton, ACT.

Shields, I. 2007. Finding Dales: The scholarly path from the Coase theorem to today's tradable emission rights, Master's thesis for the Master of Environmental and Development Economics degree, Department of Economics, University of Oslo.

Shrestha, R. K. 1998. Uncertainty and the choice of policy instruments, a note on Baumol and Oates propositions, Environmental and Resource Economics, vol. 12, pp. 497-505.

Skjærseth, J. B. 2009. EU emissions trading: legitimacy and stringency. Paper prepared for the 9th European Conference on the Human Dimensions of Global Environmental Change, 2-4 December 2009 Amsterdam.

Skjærseth, J., Wettestad, J. 2010. Making the EU emissions trading system: the European commission as an entrepreneurial epistemic leader, Global Environmental Change, vol. 20, pp. 314-321.

Smith, S., & Swierzbinski, J. 2007. Assessing the performance of the UK emissions trading scheme, Environmental Resource Economics, vol. 37, pp. 131-158.

Sonneborn, C. 2005. Industry capacity building with respect to market-based approaches to greenhouse gas reduction: US and Australian perspectives, thesis presented for the degree of Doctor of philosophy of Murdoch University.

Spiegel, J. E. 2020. Power plant emissions down 47% under Regional Greenhouse Gas Initiative. Article, Yale Climate Connections. Viewed 23 September 2020 <yaleclimatechangeconnections.org.

Sprinz, D., & Luterbacher, U. 1996. International relations and global climate change. Report 21, Potsdam institute for climate impact research (PIK). Potsdam Germany.

Stavins, R. 1989. Harnessing market forces to protect the environment. Environment, vol. 31, no. 1, pp. 28-35.

Stavins, R. 1995. Transaction costs and tradable permits, Journal of Environmental Economics and Management, vol. 29, pp. 133-148.

Stavins, R. 1998. What can we learn from the grand policy experiment? Lessons from SO_2 allowance trading, Journal of Economic Perspectives, vol. 12, no. 3, pp. 69-88.

Stavins, R. 2005. Lessons learned from SO_2 allowance trading American Agricultural Economics Association, vol. 20, no. 1, pp. 53-57.

Stavins, R. 2011. The problem of the commons: still unsettled after 100 Years, American Economic Review, vol. 101 (February 2011), pp. 81-108.

Stern, N. 2006. The economics of climate change. The Stern review. Cambridge University Press, Cambridge.

Stone, C. 1992. Beyond Rio: “insuring” against global warming, The American Journal of International Law, vol. 86, no. 3. pp. 445-488.

Strachan, N. D. 2005. The European Union emissions trading scheme (system) (EU-ETS) insights and opportunities, discussion paper, Pew Centre on Global Climate Change. Arlington, Virginia.

Su, H-N., Moaniba, I, M. 2017. Does innovation respond to climate change? Empirical evidence from patents and greenhouse gas emissions. Technical Forecasting & Social Change, 122 (Elsevier 2017), pp. 49-62.

Sussman, R. 2016. The essential role of Section 115 of the Clean Air Act in meeting the COP 21 targets. Planet Policy, The Brookings institution. Viewed 21 September 2016 < https://www.brookings.edu/blog/planetpolicy/2016/04/29/the-essential-role-of-section-115-of-the-clean-air-act-in-meeting-the-cop-21-targets/.

Svendsen, G. 1998. Towards a CO_2 market in the EU: The case of electric utilities, European Environment, vol. 8, pp. 121-128.

Svendsen, G., & Vesterdal, M. 2003. How to design greenhouse gas trading in the EU? Energy Policy, vol. 31, pp. 1531-1539.

Telli, C., Voyvoda, E., & Yeldan, E. 2007. Economics of environmental policy in Turkey: A general equilibrium investigation of the economic evaluation of sectoral emission reduction policies for climate change, Journal of Policy Modelling, vol. 30, pp. 321-340.

The American Journal of International Law. 2001. (Journal article no author listed) US rejection of Kyoto protocol process, 2001, The American Journal of International Law, vol. 95, no. 3. pp. 647-650.

Thompson, V. E. 2006. Early observations on the European Union’s greenhouse gas emission trading scheme: Insights for United States policymakers. A report in collaboration with the Pew Centre on Global Climate Change. Arlington, Virginia.

Tietenberg, T. H. 1985. Emissions trading, an exercise in reforming pollution policy. Resources for the Future, Inc. Washington D.C.

Tietenberg, T. H. Economic Instruments for Environmental Regulation, in Helm, D. 1991. Economic policy towards the environment, Oxford Review of Economic Policy, Blackwell Publishers, Oxford, pp. 86-110.

Tietenberg, T. H. 2006. Emissions trading: principles and practice. 2nd edn. Resources for the Future, Inc. Washington DC.

Tietenberg T. H. 2008. The evolution of emissions trading. Viewed 23 November 2014 < www.aeaweb.org.

Tietenberg, T., Grubb, M., Michaelowa, A., Swift, B., & Zhang, Z. X. 1998. International rules for greenhouse gas emissions trading. Defining the principles, modalities, rules and guidelines for verification, reporting and accountability. Special report United Nations conference on trade and development (UNCTAD/GDS/GFSB/Misc. 6,) United Nations Geneva.

Tulloh, C., Ahammad, H., Mi, R., & Ford, M. 2009. Effects of the carbon pollution reduction scheme on the economic value of farm production. Australian Bureau of Agriculture and Resource Economics. Issues insights, 09.6. Viewed 8 September 2016 < https://www.researchgate.net/publication/277565007_Effects_of_the_ Carbon_Pollution_Reduction_Scheme_on_the_economic_value_of_farm_production

United Nations (UN). 2012. World population prospects. The 2012 revision. Viewed 15 September 2014 < http://esa.un.org/unpd/wpp/Excel-Data/population.

United Nations Framework Convention on Climate Change (UNFCCC). 2006. UNFCCC: Handbook. Bonn, Germany: Climate Change Secretariat. Viewed 22 January 2019 < https://unfccc.int/resource/ docs/publications/handbook.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2008. Kyoto protocol reference manual on accounting of emissions and assigned amount. Viewed 7 April 2012 < http://unfccc.int/resource/docs/publications/08_unfccc _kp_ref_manual.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2008a. Kyoto protocol to the United Nations framework convention on climate change. Viewed 20 November 2014 < http://unfccc.int/kyoto_protocol/items/2830.php.

United Nations Framework Convention on Climate Change (UNFCCC). 2010. (Electronic text). Environmental indicators, GHGs. Viewed 17 October 2014 < http://unstats.un.org/unsd/environment/air.greenhouse.emissions.

United Nations Framework Convention on Climate Change (UNFCCC). 2011. Compilation of economy-wide emission reduction targets to be implemented by parties included in annex I to the convention. Viewed 13 September 2016 < http://unfccc.int/resource/docs/2011/sb/eng/inf01r01.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2012. United Nations framework convention on climate change. GHG total excluding LULUCF. Viewed 15 September 2014< http://unfccc.int/ghg.data/ghg.data.unfccc/time.series.annex.i/items /3841.php.

United Nations Framework Convention on Climate Change (UNFCCC). 2013. Statement by UNFCCC executive secretary on crossing of 400 ppm CO2 threshold. United Nations climate change secretariat. Bonn, Germany. Viewed 13 September 2016 < https://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/400_ppm_media_alert_13052013.pdf.

United Nations Framework Convention on Climate Change (UNFCC). 2014a. Annual compilation and accounting report for Annex B parties under the Kyoto Protocol for 2014. Viewed 21 September 2016 < http://unfccc.int/resource/docs/2014/cmp10/eng/07.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2014b. Status and ratification of the convention. Viewed 21 November 2014 < http://unfccc.int/essential_ background/convention/status of ratification/items/ 2631.php.

United Nations Framework Convention on Climate Change (UNFCCC). 2015. INDCs as communicated by parties. Viewed 12 August 2015 < http://www4.unfccc.int/ submissions/indc/Submission%20Pages/submissions.aspx.

United States Department of Energy Office of Fossil Fuels (US DEOFF). 2019. An energy overview of the republic of Poland. Viewed 16 June 2019< http://www.geni. org/globalenergy/library/national_energy_grid/poland/EnergyOverviewofPoland.shtml.

United States Environmental Protection Agency (US EPA). 2000. Clearing the air. The facts about capping and trading emissions. Office of Air and Radiation, Clean Air Markets Division. Viewed 17 May 2013 < www.epa.gov/airmarkets/presentations/docs/ clearingtheair.pdf.

United States Environmental Protection Agency (US EPA). 2007. The experience with emissions control policies in the United States. U.S. Environmental Protection Agency Office of Atmospheric Programs staff paper. Viewed 17 May 2013< http://www.epa.gov/airmarkets/international/china/JES_USexperience.pdf.

United States Environmental Protection Agency (US EPA). 2010. Special report. Climate Change Indicators in the United States. Viewed 13 September r2016 < https://www.epa.gov/sites/production/files/2016-08/documents/ci-full-2010.pdf.

United States Environmental Protection Agency (US EPA). 2011. Clean air interstate rule, acid rain program and former NO_x budget trading program. 2010 progress report, emission, compliance, and market analyses. United States Environmental Protection Agency, Washington DC.

United States Environmental Protection Agency (US EPA). 2012. Inventory of US greenhouse gas emissions and sinks: 1990-2010 April 15, 2012. US Environmental Protection Agency, Washington DC.

United States Environmental Protection Agency (US EPA). 2013a. Greenhouse gas reporting program. Viewed 14 February 2013 < http://www.epa.gov/ghgreporting/.

United States Environmental Protection Agency (US EPA). 2013b. 2013 Program progress. Clean air interstate rule, Acid rain program and former NO_x budget trading program. Viewed 23 October 2016 < https://www3.epa.gov/airmarkets/progress /reports/pdfs/2013_full_report.pdf.

United States Environmental Protection Agency (US EPA). 2019. SO2 Emissions from CSAPR and ARP Sources, 1980-2016. Viewed 30 April 2019 < https://www 3.epa.gov/airmarkets/progress/reports/emissions_reductions_so2.html#figure1.

Vesterdal, M., & Svendsen, G. T. 2003. Potential gains from CO_2 trading in the EU. Environmental Policy and Governance, vol. 13, issue 6, pp. 303–313.

Vesterdal, M., Svendsen, G. T. 2004. How should greenhouse gas permits be allocated in the EU? Energy Policy, vol. 32, issue 8. pp. 961-968.

Vlassopoulos, C.A. 2012. Competing definition of climate change and post-Kyoto negotiations. International Journal of Climate Change Strategies and Management, vol. 4, issue 1, pp. 104-118.

Von Malmborg, F., & Strachan, P. A. 2005. Climate policy, ecological modernization and the UK emission trading scheme, European Environment, vol. 15, pp. 143-160.

Voorspools, K., Peersman, I., & D'haeseleer, W. 2005. A comparative analysis of energy and CO_2 taxes on the primary energy mix for electricity generation, International Journal of Energy Research, vol. 29, pp. 879-890.

Walters, B., & Baird, M. 2009. Bob Brown legal advice show billions more could flow to big polluters, Australian Greens media release, senators Bob Brown, Christine Milne. Viewed 8 June 2011 < http://parlinfo.aph.gov.au/parlInfo /download/media/pressrel/J3AV6/ upload_binary /j3av 62. pdf;fileType%3Dapplication%2Fpdf.

Wang, J., Yang, J., Grumet, S., & Schreifels, J. 2011. SO_2 emissions trading program feasibility study for China. Viewed 8 June 2011< www.epa.gov/airmarkets/international/china/ feasibility.pdf.

Wang, Q., Gao, H., Wen, F., MacGill, I., & Huang, J. 2008. From command and control regulations to a business proposition, International Journal of Energy Sector Management, vol. 3, no. 1, pp. 62-82.

Wang, Q., Wang, S. 2020. Preventing carbon emission retaliatory rebound post COVID 19 requires expanding free trade and improving energy efficiency. Science of the Total Environment, 746, (Elsevier 2020).

Wara, M. 2014. California's energy and climate policy. A full plate but perhaps not a model policy, Bulletin of Atomic Scientists, vol. 70, no. 5, pp. 26-34.

Wilder, M. Implementing the Clean Development Mechanism and emissions trading beyond Europe, in Yamin, F. (ed.). 2005. Climate change and carbon markets: A handbook of emission reduction mechanisms, published by Earthscan, Cromwell Press Ltd, Trowbridge, UK, pp. 321-349.

Woolhouse, L. 2008, Lessons from the EU emissions trading scheme, achieve /article from the Sinclair Knight Merz magazine. Viewed 14 May 2008< http://www.skmconsulting.com/skm/print.aspx?id.

World Bank. 2011. State and trends of the carbon market 2011. A report by the Environment department, World Bank. Washington DC.

World Resources Institute (WRI). 2005. Navigating the numbers: Greenhouse gas data and international climate policy - part 1. Chapter 4, per capita emissions. Viewed 12 October 2016 < http://pdf.wri.org/navigating_numbers_chapter4.pdf.

Yamin, F. (ed.) 2005. Climate change and carbon markets: A handbook of emission reduction mechanisms, Earthscan, Cromwell Press Ltd, Trowbridge, UK, pp. 321-349.

Yin, R. 2003. Case study research - design and methods third edition, Sage Publications, Thousand Oaks, California.

Zerlauth, A., Schubert, U. 1999. Air quality management systems in urban regions: an analysis of RECLAIM in Los Angeles and its transferability to Vienna. Cities, vol. 16, no. 4, pp. 269-283.

Zetterberg, L. 2012. Linking emissions trading systems in EU and California. Swedish Environmental Research Institute, Ltd, Stockholm.

Appendix A

A1 EU ETS Carbon price discovery data part 1

Benz, E., Henglebrock, J. 2008. Liquidity and Price discovery in the European CO_2 Futures Market: An Intraday Analysis.

Table 57: EU ETS Carbon price discovery data part 1

Year	Contract ECX		Nord Pool	
	Mio t of CO_2	Mio Euro	Mio t of CO_2	Mio Euro
2005 Dec 05	22.96	522.79	6.76	139.89
2006 Dec 06	93.77	1 763.93	9.92	182.47
2007 Dec 07	50.24	65.22	3.10	4.03

Source: ECS, Nord Pool.

A2 EU ETS Carbon price discovery data part 2

: EU ETS Carbon price discovery data part 2

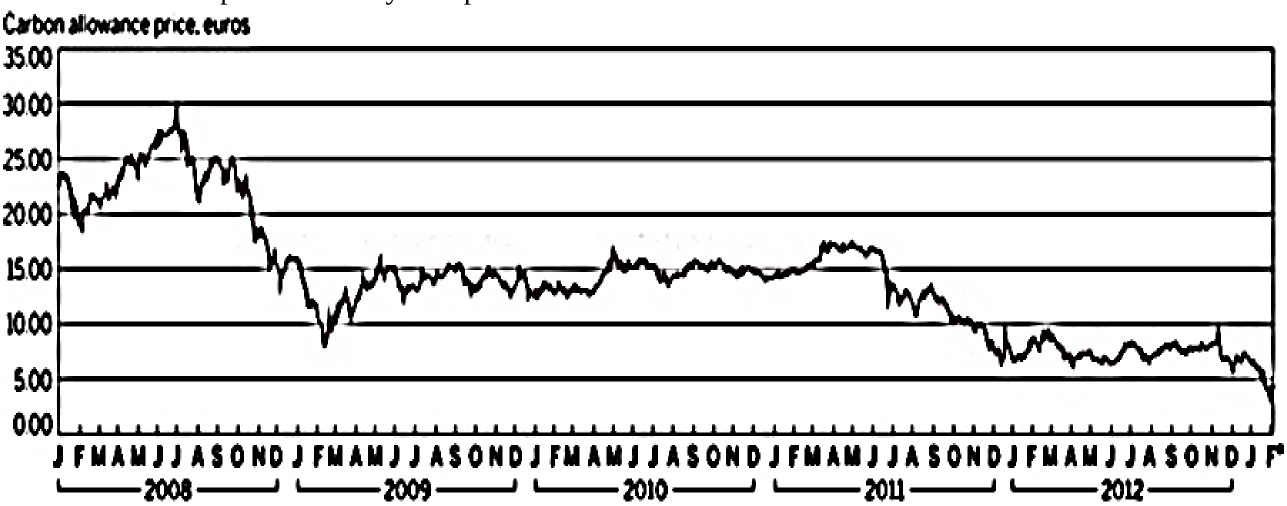

Figure 16: EU ETS Carbon price discovery data part 2

Source: Chemical and Engineering News http://cen.acs.org

Appendix B

B1 Common factors 1. US ARP 2. EU ETS 3. RGGI

Table 58: Legislation (1)

Program	Factor – legislation	Date of scheme start – gases covered
US ARP	US EPA Clean Air Act 1990	1995 – SO_2 and NO_x
EU ETS	Directive 2003/87/EC and subsequent amendments	2005 – CO_2, NO_x and PFCs
RGGI	RGGI Inc. model rule adapted to participant states' statutory framework.	2009 – CO_2

Table 59: Governance

Program	Factor – governance (Governing body)	Nature of participants
US ARP	US EPA	48 US states
EU ETS	European Commission	26 European Union nations plus three other European nations
RGGI	Board of RGGI Inc.	9 US North eastern and mid-Atlantic states

Table 60: Rules (3)

Program	Factor – rules (Administration)	Additions (as of 2013)
US ARP	US EPA	Clean Air Interstate rule (CAIR) Cross State Air Pollution Rule (CSAPR)
EU ETS	European Commission	Directive 2004/101/EC – Kyoto project credits Directive 2008/101/EC –Aviation Directive 2009/29/EC – strengthen EU commitments
RGGI	Board RGGI Inc. plus individual state bodies	Size and structure of cap, 5.3 – Banked allowances, 1.2, 1.5, 4.1, 6.5, and 7, Interim control period, 5.3(c) and 9. Cost containment reserve, 1.2 and 10.3. Offset trigger mechanisms1.2. Control period extension10.2 and 10.5. Offsets 5.2. Undistributed and unsold CO_2 allowances 10.5(d). End use energy efficiency offsets 10.5(b) SF6 Offset category.

Table 61: Compliance (4)

Program	Factor – compliance (Accounting process)	Penalties
US ARP	US EPA account	US$2000 per ton SO_2 OR NO_x
EU ETS	Community Independent Transaction Log (CITL) or (EUTL)	Approx. 100 € indexed to inflation
RGGI	Carbon Dioxide Allowance Tracking System (COATS)	Variable - set by each participating state

Table 62: Allocation (5)

Program	Factor – allowances (distribution)	Issues
US ARP	Grandfathering and auctioning	Fuel switching and innovation (scrubbers) distorted the early operation of the market. Emission reductions were more easily achieved than anticipated.
EU ETS	Grandfathering and auctioning	Oversupply of allowances. Global Financial Crisis also reduced emissions intensity. Very unstable allowance price.
RGGI	Auctioning	Auction process appeared to distribute allowances efficiently. Low allowance price in first compliance period.

Table 63: Compensation (6)

Program	Factor – allowances (Surplus)	Subsequent treatment
US ARP	Initial free allocation led to oversupply. Rent seeking behaviour resulted.	The US ARP moved full auctioning of allowances.
EU ETS	Free allocation led to oversupply. Rent seeking behaviour resulted. GFC created low prices and excess allowances.	A market stability reserve for excess allowances was created. Moved to auctioning of allowances and increased coverage to include the marine and aviation sectors.
RGGI	Auctioning of allowances provided revenue for redistribution. Easily attained targets created low prices and excess allowances.	Containment reserve was created to control the level of allowances in the market. The price of allowances was controlled by a price floor and price collar.

Table 64: Targets (7)

Program	Factor – initial targets	Factor – subsequent targets
US ARP	Ten million tons per year reduction from 1980 levels of SO_2 by 2000 by one hundred and ten of the most heavily polluting installations.	Program expanded to cover essentially all fossil fuel installations. Each unit required to reduces emissions by 3.5 million tons per year.
EU ETS	Initial targets aligned to Kyoto Protocol with burden sharing among nations	Whole of EU target adopted for phase three.
RGGI	Initial stabilisation of emissions to 2005 levels. Later modified to a 2014 cap of ninety million tons.	From 2015, a 2.5% reduction of emissions annually.

Table 65: Coverage (8)

Program	Factor – coverage (Industrial sectors)	Gases
US ARP	Stationary energy	SO_2 and NO_x
EU ETS	Sectors related to stationary energy, other intensive energy industries and commercial aviation (phase three) Perfluorocarbons from the production of aluminium.	CO_2, N_2O and PFCs.
RGGI	Stationary energy	CO_2

Table 66: Phased introduction (9)

Program	Factor – phasing in (first stage)	Factor – phasing in (second stage)
US ARP	Phase one began 1995.	Phase two followed from 2000
EU ETS	Initial phase of three years to facilitate so called learning by doing in the period 2005-2008.	Phase two followed of five-year duration 2008-2012. Currently in phase three 2013-2020.
RGGI	Completed first reporting period of three years 2009-2011.	Currently in the fourth reporting period 2018-2020.

Appendix C

C1 Group 1 ARP features in EU ETS & RGGI

Table 67: Evidence for the key US ARP factors for the EU ETS (Group 1 1998-2005)

Evidence for a factor found	No evidence for a factor found
Emission caps	Reduced cost of Compliance
Fixed annual cap	Stringent environmental standards
Targeted emissions reductions achieved	Penalties for non-compliance (fines and forfeiture of allowances)
Allowance trading	Allowances auctioned
Allowances are clearly defined to allow trade without case by case verification	Compliance encouraged by high (US $2000 per ton) penalty.
Majority of allowances issued free through a grandfathering clause (In Phase One)	While the original motivation was the mitigation of acid rain, human health improved
Allowance market was slow to develop due to external forces	Phased introduction
Banking of allowances.	Compliance encouraged by high (US $2000 per ton) penalty
Compliance	Majority of allowances issued free (Not in Phase 2)
Rules for monitoring reporting and verification	Allowance market was slow to develop due to external forces
Intra and inter facility trades	
Penalties for non-compliance (fines and forfeiture of allowances in the second phase)	
Self-reporting to public database	
Cost-effectiveness results from trade between facilities.	
Success in lowering the cost of meeting emission reduction goals	
Enhanced the achievement of environmental goals	
Banking improves economic and environmental performance	
Targeted electricity sector	
Accurate measurement of emissions	
Inherent flexibility facilitated fuel switching	
Phased introduction	
Fostered innovation	

Table 68: Evidence for the key US ARP factors in the RGGI (Group 1 1998-2005)

Evidence for a factor found	No evidence for a factor found
Targeted emissions reductions achieved	Emission caps (Stabilisation was the goal)
Allowance trading	Stringent environmental standards
Allowances auctioned	While the original motivation was the mitigation of acid rain, human health improved
Banking of allowances.	Allowance allocation ultimately capped at 8.95 million tons in 2010
Banking improves economic and environmental performance	Single national market adopted after regional model was dropped due to cost considerations
Allowances are clearly defined to allow trade without case by case verification	Environmental improvement slower to be realised than the public health benefits were
Reduced cost of Compliance	Largest and dirtiest facilities could reduce emissions most easily
Compliance	During phase two the cost savings estimated to be 43% of compliance costs
Rules for monitoring reporting and verification	Supported cost reducing innovations
Self-reporting to public database	
Cost-effectiveness results from trade between facilities.	
Success in lowering the cost of meeting emission reduction goals	
Enhanced the achievement of environmental goals	
Targeted electricity sector	
Accurate measurement of emissions	
Inherent flexibility facilitated fuel switching	
A measure of efficiency is the convergence of the marginal cost of abatement to the price of allowances in the market	

C2 Group 2 ARP features in EU ETS & RGGI

Table 69: Evidence for the key US ARP factors in the EU ETS (Group 2 2011-2013)

Evidence for a factor found	No evidence for a factor found
Initial coverage in phase one was less than phase two coverage	Ultimate cap approx. 50% of 1980 emissions
Trading volume was initially low then increased at later stages	A share of allowances removed from the market to cater for new entrants
Price volatility due to excess allowances and innovative controls	Environmental performance exceeded expectations
Cost-effectiveness difficult to assess as there is no reference case	Bigger is better
A large range of participant abatement cost results in more efficient markets	Price fluctuations should be anticipated in market design
Banking increases temporal flexibility	Bigger markets increase transaction costs
Banking allowed smoothing of allowance price variations	
Auctioning may be superior to free allocation	Rent seeking behaviour encouraged by Over allocation of allowances
Bigger markets increase transaction costs	Scheme design should allow for later modifications
Clear rules required for monitoring, reporting and verification	Penalties for non-compliance significantly higher than anticipated compliance costs
Rent seeking behaviour encouraged by Over allocation of allowances	External factors (e.g. railroad deregulation) resulted in low cost low sulphur coal
A decentralised (state based) system may have benefits due to the large number of sources	Original scheme design was guided by heuristic (trial and error) analysis
Scheme design should allow for later modifications	Expensive monitoring in real time was initially opposed but proved beneficial to some participants
Penalties for non-compliance set in statute	Action to reduce emissions in one region benefitted geographically distant areas
Older facilities disadvantaged as compared to newer facilities built under more stringent standards	Local and state regulation was important to avoid so called hot spots
Original scheme design was guided by heuristic (trial and error) analysis	Technology was available (scrubbers) to remove sulphur from emissions
Additional innovative solutions were found (e.g. mining techniques)	Additional innovative solutions were found (e.g. mining techniques)
In the US senate the political support of the Bush administration (of 1989) was underpinned by significant academic rigour	The stakes are higher in addressing CO_2 than they were for the SO_2 program
The stakes are higher in addressing CO_2 than they were for the SO_2 program	Free allocation of the initial allowances
Free allocation of the initial allowances	Moderate coverage of single sector (electricity) during phase one
Threat of policy reversal due to changing political landscape	Wider coverage of single sector (electricity) during phase two
	Cost saving estimated to be at least 15% over traditional command and control measures

Evidence for a factor found	**No evidence for a factor found**
	Environment did not recover as quickly as predicted
	Unforeseen health benefits
	Railway deregulation provided cheaper low sulphur coal
	Irony in that the conceptual aspects of cap and trade became confused between two main political parties
	Early low allowance prices remained stable for a decade

Table 70: Evidence for the key US ARP factors in the RGGI (Group 2 2011-2013)

Evidence for a factor found	No evidence for a factor found
A share of allowances removed from the market to cater for new entrants	Initial coverage in phase one was less than phase two coverage
Cost-effectiveness difficult to assess as there is no reference case	Ultimate cap approx. 50% of 1980 emissions
Banking increases temporal flexibility	Trading volume was initially low then increased at later stages
Banking allowed smoothing of allowance price variations	Price volatility due to excess allowances and innovative controls
Price fluctuations should be anticipated in market design	Environmental performance exceeded expectations
Auctioning may be superior to free allocation	Bigger is better
Clear rules required for monitoring, reporting and verification	A large range of participant abatement cost results in more efficient markets
A decentralised (state based) system may have benefits due to the large number of sources	Bigger markets increase transaction costs
Penalties for non-compliance set in statute	Rent seeking behaviour encouraged by Over allocation of allowances
Older facilities disadvantaged as compared to newer facilities built under more stringent standards	
In the US senate the political support of the Bush administration (of 1989) was underpinned by significant academic rigour	Scheme design should allow for later modifications
Unambiguous level of the cap for emissions	Penalties for non-compliance significantly higher than anticipated compliance costs
Cost saving estimated to be at least 15% over traditional command and control measures	External factors (e.g. railroad deregulation) resulted in low cost low sulphur coal
Threat of policy reversal due to changing political landscape	Original scheme design was guided by heuristic (trial and error) analysis
State level regulations eventually superseded group rules	Expensive monitoring in real time was initially opposed but proved beneficial to some participants
Moderate coverage of single sector (electricity) during phase one	Action to reduce emissions in one region benefitted geographically distant areas
	The stakes are higher in addressing CO_2 than they were for the SO_2 program
	Free allocation of the initial allowances
	Wider coverage of single sector (electricity) during phase two
	Target for emissions cap set at ‘elbow’ point where abatement costs anticipated to be relatively low
	Free initial allocation of allowances
	Unforeseen health benefits
	Early low allowance prices remained stable for a decade
	Later allowance prices spiked when rules where modified

Glossary of websites

http://www.aeaweb.org
http://www.bea.gov
http://www.bom.gov.au
http://www.c2es.org
http://www.cdcclimat.com
http://www.chicagoclimatex.com
http://www.cen.acs.org
http://www.climatechange.gov.au
http://www.climatepolicy.com
http://www.commerce.gov/
http://www.co2now.org
http://www.eea.europa.eu
http://www.eia.gov
http://www.ifrs .org
http://www.ipart.nsw.gov.au
http://www.lse.ac.uk
http://www.unfccc.int
http://www.news.bbc.co.uk
http://www.nsi.bg
https://icapcarbonaction.com
http://www.ipcc.ch
http://www.epa.gov
http://www.europa.eu
http://www.elsevier.com
http://www.epp.eurostat
http://www.garnautreview.org.au
http://www.home.heinonline.org
http://www.law.nyu.edu
http://www.masshightech.com
http://www.parlinfo.aph.gov.au
http://www.pandora.nla.gov.au
http://www.papers.ssrn.com
http://www.pointcarbon.com
http://www.skmconsulting.com
http://www.springer.com
http://www.vu.edu.au
http://www.pdf.wri.org
https://au.finance.yahoo.com