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Lessons Learned in Mandatory Carbon Market Development

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ABSTRACT

The Kyoto Protocol introduced the notion of a global emissions trading scheme (ETS) to aid in meeting global emissions reduction targets. Since then, the share of emissions covered by carbon pricing has tripled and now encompasses approximately 12% of global emissions. This paper discusses the challenges in design and implementation of past and current ETSs to provide recommendations for ETS development and linkage. It summarizes seven major factors that should be considered for successful ETS implementation: cap setting, permit allocation, trading guidelines that avoid carbon leakage, regulation of offsets, high compliance, transparent and continuous monitoring, and careful collaboration between systems. Successes and failures in practical implementation of each factor are explored through various ETS case studies. If applied carefully, these factors could ensure high and consistent carbon prices, and coupled with strict

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regulations, could achieve an ETS that meets intended environmental benefits, while offering potential for bottom-up international linkage.

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1 Introduction

Due to the global nature of climate change, international cooperation is a requirement of any solution that will effectively limit global temperature rise to well below 2°C and hopefully avoid the most severe impacts of climate change (Kossoy *et al.*, 2015a). Agreement over pursuing efforts to hold the warming increase to 1.5°C above pre-industrial levels was a major outcome of the Paris Agreement and will require an estimated emissions reduction of 40–70% from 2010 levels by 2050 (IPCC, 2014; UNEP, 2014; World Bank and Group, 2016). However, achieving this goal will require more aggressive and large-scale action than the current policies and Nationally Determined Contributions (NDCs) of the Paris Agreement (Kossoy *et al.*, 2015a; UNFCCC, 2015).

The disjunction between ambitious climate targets and inadequate policies and practices is not uncommon, and the potential use of a global emissions trading scheme (ETS) as a strategy to help meet such targets was popularized by the Kyoto Protocol (KP) in 2005 (Roppongi *et al.*, 2016; UN, 1998). Since then, the share of emissions covered by carbon pricing has tripled and, by August 2015, 39 national jurisdictions and 23 cities, states, and regions had implemented a price on carbon, encompassing approximately 7 $GtCO_2e$ (12% of global emissions) (Kossoy *et al.*, 2015a). The combination of all carbon pricing mechanisms is estimated to have a value of US$50 billion globally in 2015, with 70% attributed to ETSs and 30% to carbon taxes (Kossoy *et al.*, 2015a). Development of an international carbon market continues to be an important topic in climate policy discussion and has been acknowledged in the Paris Agreement as a necessary tool for addressing climate change (Johannsdottir and McInerney, 2016).

An ETS is a market-based approach to controlling greenhouse gas (GHG) emissions in which government places a cap on aggregate emissions and distributes emissions permits equal to that of the cap (Doda, 2016). Permits (or allowances) are allocated to participating entities, allowing emissions of the equivalent tonnes of CO_{2e}. These permits are tradeable in the carbon market, whereby trading activity determines the price of an emissions permit (Doda, 2016). This type of system has been used in the past for other types of pollutants, including SO_2 trading under the 1990 Clean Air Act in the United States. The rationale behind this system is to enable emissions reductions to take place where the cost of reduction is lowest, thereby minimizing the overall cost of addressing climate change, while still taking positive environmental action by encouraging participating entities to limit their GHG emissions (DECC, 2015). For the purpose of this analysis, a successful carbon market or ETS is synonymous with one that leads to substantial emissions reductions. The most mainstream ETS design is cap-and-trade, which involves an absolute cap on emissions above a baseline level and the trading of additional emissions wherein permits can be sold or purchased if emissions levels are less than or exceed the cap, respectively (Kill *et al.*, 2010; Roppongi *et al.*, 2016).

Along with being cost-effective, carbon markets should, in principle, encourage innovation, investment in low-carbon technologies, and efficient use of fossil fuels (Kossoy *et al.*, 2015a). These systems are especially important as they are the strategies that have been most widely adopted to date in addressing climate change (Knudsen, 2015; Kossoy *et al.*, 2015a). The scale of emissions reductions necessary to meet global targets is daunting, and therefore cost-effective mitigation strategies such as carbon pricing will likely provide quicker, more substantial emissions reductions. Carbon markets present a promising opportunity, however their potential can only be realized if the price of carbon is sufficiently high and consistent such that intended environmental benefits are achieved (Kill *et al.*, 2010). While a carbon market may be perfectly functional despite a low carbon price, there is a limited incentive for environmental effectiveness and global emissions reductions may exceed those projected in order to comply with our global climate change targets. The majority of 2015 emissions were priced at less than US\$10 per tCO_2e (Kossoy *et al.*, 2015a), however it has been estimated that a global average carbon price between US\$80 and US$120 per tCO_2e in 2030 is consistent with achieving a warming of 2°C (Clarke *et al.*, 2014; World Bank and Group, 2016).

Carbon markets have been introduced around the world at varying levels of enforcement; examples include sub-national implementation in Canada and Japan, regional implementation in the United States, national implementation in New Zealand and Switzerland, and supranational implementation in Europe (Ranson and Stavins, 2016). There are currently 38 countries in the world operating 16 carbon market systems, in addition to the international emissions trading mechanisms established under the Kyoto Protocol, all of which exemplify varying characteristics, strategies, linking potential, and levels of success. Although the basic principle of emissions trading is simple and appealing, complexity occurs in the political and technical challenges of implementing these systems in practice (Cullenward, 2014; Helm, 2003). Most commonly in carbon market implementation, two features predominately determine the environmental and economic viability of the system, namely; a high emissions cap that does not produce actual emissions reductions, and a low carbon price that fails to incentivize desired behaviors.

For the purpose of this review, seven major features have been identified as crucial to determining the success of an ETS, including: cap setting, allowance allocation, coverage, offsetting, commitment and ambition, MRV (monitoring, reporting, and verification), and international linkage. If implemented poorly, the combination of these factors can lead to an overall increase in emissions, contradictory to the initial intent of these systems (Kill *et al.*, 2010). This paper aims to address each of these seven key challenges in ETS design and implementation, demonstrating the common downfalls made in regards to each of these factors and providing suggested improvements. It reviews the main issues and measures taken to overcome such issues through examining the lessons that have been learned from carbon market development to date, with the goal of providing a framework for future development of an environmentally and economically viable ETS and eventual linkage of a global carbon market network.

2 Global Status and Development Trends of Carbon Markets

Eleven example ETSs are used as case studies throughout this paper to demonstrate variations in the seven factors discussed earlier. These include the European Union (EU) ETS; the Western Climate Initiative (WCI); the Regional Greenhouse Gas Initiative (RGGI); the New Zealand ETS; the Japanese ETSs; Kazakhstan ETS; the Swiss ETS; the Chicago Climate Exchange (CCX); the South Korea ETS; the Pacific Carbon Trust (PCT); and the Chinese Pilot ETSs.

The EU ETS is the world's largest and longest running cap-and-trade system (Ellerman *et al.*, 2015; European Commission (EC), 2016; Lucia *et al.*, 2015), including 31 participating countries (28 member states and Norway, Iceland, and Liechtenstein) (EC, 2016; Ellerman *et al.*, 2015) and covering approximately 45% of the EU's total emissions (EC, 2013; Ellerman *et al.*, 2015; Kopsch, 2012). The Swiss ETS is currently under negotiations for linking to the EU ETS (Federal Office for the Environment, 2016). In North America, the WCI is the largest, most comprehensive GHG trading collaboration, with three participating jurisdictions (California, Quebec, and Ontario) having successfully implemented ETSs (Houle *et al.*, 2015; Government of Ontario, 2016). A smaller scale carbon market in North America is the RGGI, a cooperative effort among nine Northeastern American states (namely Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) to cap CO_2 emissions in the power sector (Fell and Maniloff, 2015; RGGI Inc., 2016). The PCT and CCX are two examples of past ETSs in North America that have been dissolved, providing a learning opportunity for existing and future schemes (Gans and Hintermann, 2013; PCT, 2016).

Cap-and-trade systems in Asia and Oceania include New Zealand, Japan, Kazakhstan, China, and South Korea. New Zealand's ETS is unique in that it is run in a bottom-up design with no fixed cap and the system officially includes the forestry sector (ICAP, 2016). Japan has two city-sized ETSs in Tokyo and Saitama, which are nearly identical in design and, despite being small in scale, have led to significant emissions reductions (Roppongi *et al.*, 2016; Rudolph and Kawakatsu, 2012). Kazakhstan, on the other hand, has taken a larger-scale approach, implementing a mandatory nationwide ETS in 2013 (ICAP, 2016). The future of this system is uncertain, however, with a new incoming government in 2016 suspending the system for two years (until 2018) following protests from the industrial sector in the country (Climate Policy Observer, 2016). Similarly South Korea implemented a nationwide ETS in January 2015, which includes the use of additional allowance credits as rewards for early reduction (Heo, 2015). In China, seven pilot systems were implemented in two provinces (Guangdong and Hubei) and five cities (Beijing, Shanghai, Tianjin, Shenzhen, and Chongqing) in 2011, encompassing a population of 199 million in 2010 (18% of the national population) (Qi and Chen, 2015), with the goal of developing a national ETS in 2017 (Liu *et al.*, 2015; Wang, 2016). Although China faces unique challenges in the development of a national ETS (such as tight government regulation of pricing and the immense size of the system), it holds an important responsibility in the international community to make wise decisions regarding carbon market development and linkage.

3 Issues and Challenges in ETS Design

3.1 Cap Setting

Debatably the most crucial component of an ETS is the emissions cap (Cullenward, 2014; Kill *et al.*, 2010), as the cap determines the level of ambition and allows for emissions reductions to occur. The most common issue to occur in cap setting is an emissions cap that is too high or not sufficiently stringent, as this can lead to a low carbon price and limited environmental benefits. This issue is currently exemplified in the Chinese pilot ETSs, which currently experience weak caps and a low carbon price as a result of their cap setting methodology.

At the end of 2011, the Chinese government selected seven areas (five cities and two provinces) to establish pilot emissions trading systems (Zhang *et al.*, 2014), with the goal of testing various methodologies and identifying the most successful attributes to implement in an effective national carbon market in 2017 (Liu *et al.*, 2015; Swartz, 2016). The seven pilot ETSs have many unique characteristics, including their cap setting approach. The pilot systems generally use a two-step methodology for cap setting by first making projections of their emissions and aggregating allowances distributed to all participants to create the cap, then dividing overall emissions into a trading system cap and non-trading system cap, considering issues such as sectoral growth (Duan *et al.*, 2014; Pang and Duan, 2015). These caps can be considered intensity caps, as they are based on projected GDP growth, emissions targets, and national intensity targets (Duan *et al.*, 2014). Within this complex system, each pilot ETS has designed its cap differently, with Beijing, Shanghai, Tianjin, and Shenzhen maintaining a consistent emissions cap, while Hubei increases its cap between years to accommodate economic growth, and Chongqing reduces its cap each year, much like a traditional cap-and-trade system (Xiong *et al.*, 2016).

Major challenges with China's pilot cap setting approach include the bottom-up structure and the use of an intensity-based (as opposed to an absolute) cap that does not decrease over time (in most pilot regions). While intensity-based caps are not necessarily less stringent than absolute caps, the NRDC will need to strongly enforce intensity targets to ensure an effective ETS (Swartz, 2016). The incentive for implementing an intensity target and a flexible cap is the ability to lower uncertainty regarding the cost of emissions reductions (Pang and Duan, 2015); however, the combination of these factors has led to a low carbon price of US$4–8 in 2015 (Kossoy *et al.*, 2015b), with some arguing that the aforementioned issues and lack of real-time carbon pricing make China's current carbon system dysfunctional (Liu *et al.*, 2015). China's flexible cap is better accepted by enterprises and economic authorities, however this cap setting strategy must be reexamined carefully in the development of a national system, as it provides limited environmental benefits and will lead to higher social abatement costs in the future (Pang and Duan, 2015).

Proposed solutions to these issues include enforcing a strict, emissions cap that lowers each year to ensure emissions reductions, and applying strict rules to ensure compliance of the cap. Various systems have demonstrated that a top-down cap setting approach is generally a more rigorous and effective strategy, albeit less flexible and more challenging to meet. Top-down systems that exemplify this approach include California and Quebec, and the European Union, wherein the cap is set and gradually decreased each year to encourage emissions reductions (ICAP, 2016). Similarly, the Tokyo and Saitama ETSs exemplify a rigorous emissions cap that has produced significant small-scale emissions reductions through a bottom-up carbon market approach (ICAP, 2016).

The EU ETS market operates as a traditional cap-and-trade system in which a fixed number of emissions allowances are issued each year. A portion of allowances are freely allocated by the government, and companies are required to surrender allowances for every tonne of CO_{2e} emitted, wherein any additional emissions allowances can be purchased or surplus allowances from the previous year may be used (DECC, 2015;

European Commission (EC), 2016). During its third phase (2013–2020), the cap will gradually decrease by reducing the number of available allowances by 1.74% of the average Phase II cap annually (DECC, 2015; Ellerman *et al.*, 2015). Similarly, in California, Quebec, and Ontario, the cap reduction is approximately 3% per year (ICAP, 2016).

The Tokyo Metropolitan Government (TMG) ETS and Saitama ETS, which are nearly identical in design and unilaterally linked together, are unique in many aspects and demonstrate many effective approaches that can and should be implemented elsewhere (Roppongi *et al.*, 2016; Rudolph and Kawakatsu, 2012). The TMG ETS was the first cap-and-trade program in the world to cover facilities such as commercial buildings, including over 1,000 office buildings and 300 factories, accounting for greater than 20% of Tokyo's annual GHG emissions (TMG, 2010). By 2014 emissions reductions had declined by 25%, a portion of which can be attributed to energy savings measures taken after the Fukushima nuclear disaster in 2011; however, emissions reductions measures were implemented prior to the incident, which went beyond the required savings and continued after the energy saving requirements (Rudolph and Morotomi, 2016). These ETSs are known for strict control and regulation of their policies and are a particularly good example of cap setting methodology. In the TMG ETS, for example, the cap for participating facilities is set at 6% below baseline emissions (average of three consecutive years between 2002 and 2007) for the first compliance period (2010–2014) and 17% below for the second compliance period (2015–2019), resulting in an absolute cap of 10.44 million tCO_2 in 2020 (Roppongi *et al.*, 2016; Rudolph and Kawakatsu, 2012). This system is considered to be successful, as it has led to significant reductions in CO_2 emissions, including a 23% reduction in base-year emissions by 2013, with 90% of facilities achieving their first reduction target and 69% of them already meeting their 2019 target (Roppongi *et al.*, 2016). As such, this system demonstrates the effectiveness of implementing a compulsory monitored cap that is strictly regulated (Roppongi *et al.*, 2016). The Saitama system has also been successful, achieving a 22% reduction in base-year emissions by 2013 (ICAP, 2016).

3.2 Allowance Allocation

An allowance allocation methodology is another crucial aspect of an ETS design. For the purpose of this review, an allowance allocation includes both the method and amount of credits allocated within a system. In theory, allowance allocation methodology does not affect emissions reductions, but rather affects the cost distribution within the ETS (United Nations (UN), 2002); while the amount of allowance credits allocated, on the other hand, can affect the price and environmental integrity. Poorly executed allowance allocation can lead to a low carbon price and minimal environmental benefits, either through free allocation, over-allocation, or inaccurate allocation. Too many freely available allowances will fail to produce the substantial incentive needed to generate serious emissions reductions, while oversupply will lead to a low cost of allowances and may hinder the environmental integrity. This issue is currently exemplified by the two largest ETSs in the world — the EU ETS and China's pilot systems.

The EU ETS was launched in 2005 as the world's first, largest and longest running cap-and-trade system (EC, 2016; Ellerman *et al.*, 2015; Lucia *et al.*, 2015). It is a centralized ETS with a single regulatory body (European Commission) and a single compliance instrument (EU allowance) that is used by all 31 participating countries (EC, 2013; 2016; Ellerman *et al.*, 2015; Kopsch, 2012). Due to its size and status, this system has been highly reviewed and criticized, and continues to struggle with a few areas of concern — primarily the collapse of allowance prices threatening the stability of the system in its entirety (EC, 2016; Ellerman *et al.*, 2015; Kopsch, 2012). There are multiple complex reasons for the low allowance price in the EU ETS, but for the purpose of this section the allocation methodology with be emphasized. At the end of Phase I there was a market surplus of 83 million allowances due to National Allocation Plans, however no allowances were carried via banking into Phase II (Ellerman *et al.*, 2015). At the end of Phase II, there was a market surplus of 1.8 billion allowances which, according to the design of this ETS, were available for banking in Phase III and subsequent periods (Ellerman *et al.*, 2015). Such a significant surplus in allowances led to a decrease in allowance prices (from EUR30 per tonne at their peak in 2006 to less than EUR5 per tonne at the start of Phase III) and to criticism of the system, as a low allowance price reduces the incentive for innovation, emission reductions, and investment in low-carbon technologies (Ellerman *et al.*, 2015).

The EU ETS has experienced great volatility within the system, arguably in part due to features such as over-allocation, grandfathering, and banking of allowances (Kill *et al.*, 2010). In Phase I, permits were freely allocated to entities via grandfathering wherein companies received more emissions allowances than required, and companies were given an opportunity to sell permits short with the belief that they would later be able to buy back permits at a cheaper price (Kill *et al.*, 2010). While the banking of allowances was not permitted until the end of Phase II, a large surplus of credits still persisted in the market. Factors independent of the original market design of the EU ETS also contributed to the weak EU price signal, including the global economic recession of 2008, overlapping climate policies, and the large influx of Certified Emissions Reductions (CERs) and Emissions Reduction Units (ERUs) (Koch *et al.*, 2014). The banking of allowances, in combination with the economic downturn in 2008, allowed the low value of allowances to persist into phases II and III (Kill *et al.*, 2010; Kopsch, 2012). Additionally, overlapping policies and more notably the renewable energy policies of member states displaced GHG emissions in the market and therefore reduced allowance demand and price (Koch *et al.*, 2014). Finally, the massive influx of CERs/ERUs into the EU ETS in Phase II also contributed to the decrease in the domestic allowance demand and price, as it is estimated that over 60% compliance of the 2008–2020 quota had already been met by 2012 (Koch *et al.*, 2014). Actions are now being taken to address this instability in the market, in part by phasing out grandfathering of emission credits completely by 2027 (Ellerman *et al.*, 2015). Nonetheless, the EU ETS provides a valuable example of the interaction between external factors and market design.

The Chinese pilot ETSs also face issues in allowance allocation, particularly due to free allocation and ex-post adjustment of permits. As previously mentioned, the seven pilot systems differ in design features (including allowance allocation methodology) depending on unique characteristics and priorities (Zhang *et al.*, 2014). Virtually all permits are freely allocated based on a few reported years of historical emissions (reference periods varying between pilot sites), aside from a small number auctioned in Guangdong, Shenzhen, Beijing, and Hubei (Duan *et al.*, 2014; Wang, 2016; Zhang *et al.*, 2014). Although auctioning is a more economically efficient method of allocation, the majority of allowances are freely allocated in order to decrease the burden on enterprises, encourage economic development, and improve political acceptance (Duan *et al.*, 2014; Pang and Duan, 2015; Wang, 2016; Zhang *et al.*, 2014).

A unique and important aspect of the Chinese pilot schemes is the administrator's right to adjust permit allocations at the end of the compliance period in order to moderate market volatility, maintain a stable carbon price, and protect enterprises that provide an essential public service (Pang and Duan, 2015; Wang, 2016). This feature is called ex-post adjustment, and refers to the addition or removal of emissions allowances after the compliance period if actual emissions vary greatly from the prediction. It is used mainly in the electricity and heat generation sectors to accommodate for tight market regulation (Pang and Duan, 2015).

Depending on the sector in question, four different permit allocation methods are employed in the Chinese system: grandfathering with or without ex-post adjustment, and benchmarking with or without ex-post adjustment (Duan *et al.*, 2014). This methodology often leads to an over-allocation of allowances, especially due to the use of historical emission intensities in grandfathering, which in China is based on higher GDP values than the current GDP, a phenomenon resulting from China's economic slowdown (Xiong *et al.*, 2016). These features of the Chinese ETS demonstrate prioritization of economic development over environmental benefits (Zhang *et al.*, 2014). Ex-post adjusted allocations are meant to improve the flow of the market, but in reality often lead to a lower reduction in emissions, and, along with the bottom-up cap setting approach discussed earlier, lead to a flexible and weak system cap (Pang and Duan, 2015).

An ideal solution to the problems encountered in allowance allocation is to increase the percentage of emissions that are auctioned as opposed to freely allocated, assuming a price floor exists at auction and allowances are withheld when the price floor is reached. Auctioning emissions allowances has the ability to increase price transparency and ensure that a predictable volume of emissions allowances enter the market, both of which additionally encourage secondary market trading — the market among private buyers and sellers which arises to meet compliance demand and reduce susceptibility to price changes (Center for Climate and Energy Solutions (C2ES), 2016). A successful example of allowance allocation is demonstrated in the Western Climate Initiative (WCI). The WCI is the largest, most comprehensive GHG trading agreement in North America and includes three currently operating ETSs in California, Quebec, and more recently Ontario (WCI, 2013). While it may be premature to speculate on the successes of Ontario's cap-and-trade system, the California and Quebec systems have maintained high carbon prices with the use of a mixed allocation system, where the number of freely allocated allowances decreases each year (ICAP, 2016). More than 10% of allowances are auctioned in California and no free allowances are allocated to electricity or fuel distributors in Quebec (ICAP, 2016). Quebec's carbon price has remained above CAD$10 and allowed for an 8% reduction in GHG emissions compared to 1990 levels by 2012, along with raising money for the Green Fund (estimated $3.3 billion by 2020) to help finance a greener economy (Dahan *et al.*, 2015). California has also experienced success with this method, with a carbon price of US$13 in 2015 (Kossoy *et al.*, 2015a; Kossoy *et al.*, 2015b).

The other North American ETS, RGGI, auctions 100% of emissions permits (Hibbard *et al.*, 2015; ICAP, 2016; Kopsch, 2016). Unlike the WCI, this system only targets the power sector (fossil fuel plants that are 25 MW or more in size) and has a centralized administrative infrastructure system (called RGGI Inc.) to help run the program and conduct quarterly auctions of allowances (Hibbard *et al.*, 2015; Kopsch, 2016), in addition to the use of a common compliance instrument (Haites, 2016). Power plants can obtain emissions allowances by purchasing them through auctions or by purchasing/transferring them in a secondary market (Hibbard *et al.*, 2015). The use of auction proceeds varies from investment in energy efficiency programs, to investment in installments of renewable or advanced power generation systems, education and job training programs, and other GHG emissions reduction initiatives (Hibbard *et al.*, 2015).

As opposed to auctioning all allowances, the two Japanese ETSs employ a unique strategy to allocate allowances, with no free allocation of tradeable credits (Roppongi *et al.*, 2016; Rudolph and Kawakatsu, 2012). Emissions rights are grandfathered to participating entities at the beginning of the compliance period, however tradeable credits can only be earned by the holder reducing emissions during the compliance period (Roppongi *et al.*, 2016). The TMG and Saitama ETSs have made this allocation method more acceptable to stakeholders by operating under longer compliance periods (five years) to allow for long-term planning and goal setting (Roppongi *et al.*, 2016). This ensures that participating entities are able to meet their reduction targets and adhere to the strict allowance trading regulations. As previously mentioned, while these systems have facilitated emissions reductions, their inability to immediately trade credits by nature inhibits the ability to directly compare and recommend solutions to other ETSs.

Additionally, price control mechanisms can play a crucial role in allowance permit prices. While in theory allowance prices are determined by supply and demand, allowance prices can fluctuate due to a multitude of factors in the near-term, including economic activities and regulated entities' marginal abatement costs (Qi and Wang, 2013). Price control mechanisms can be implemented in an ETS in order to help stabilize prices and reduce market uncertainty. Price floors have been implemented in WCI member jurisdictions and RGGI, and prevent a complete collapse of allowance prices through the auctioning of credits and grants the ability to tighten the cap if a surplus of allowances remains at the price floor for an extended period of time (Fell and Maniloff, 2015; Kossoy *et al.*, 2015b). Price floors may be particularly valuable in the early stages of ETS implementation, as they can prevent a collapse in price as a result of an initially loose cap and can provide certainty to investors regarding investments in abatement technologies (Qi and Wang, 2013). For example, WCI member jurisdictions have implemented price floors at US$10/tonne CO2e in 2012 set to increase at 5% annually, while the price floor in RGGI was set at approximately US$2/tonne CO2e and is set to increase at 2.5% per annum (Wood and Jotzo, 2011).

Price ceilings, on the other hand, set a maximum price that ensure that allowance prices will not exceed some limit. However, if the price remains at or near the ceiling for an extended period of time, government intervention is required to increase the supply of allowances which subsequently raises the cap, limiting environmental effectiveness (Qi and Wang, 2013). Allowance price containment reserves are another form of price control mechanism that have been currently implemented by WCI member jurisdictions and RGGI, while the EU ETS is proposing the addition of a market reserve beginning in 2021 (International Emissions Trading Association (IETA), 2014). For example, the RGGI Cost Containment Reserve is designed to contain costs and prevent prices from exceeding the trigger allowance price, which was set at US$4/tonne CO_{2e} in 2014, increasing at 2.5% annually (IETA, 2014). In the California

ETS, the Allowance Price Containment Reserve (APCR) consists of allowances withheld from auction at 1%, 4%, and 7% of allowances in the first, second, and third compliance periods, respectively (IETA, 2014). The APCR in the Quebec system is virtually identical in design to that of the California ETS, and is used as a "soft ceiling price" wherein reserve allowances are made available if allowance prices surpass some threshold (IETA, 2014). Such price containment measures should be taken into careful consideration in the design and implementation of an ETS, as they aid in allowance permit price volatility and uncertainty for participating entities.

3.3 Coverage

Coverage, in this case, refers to the amount of emissions that are covered by an ETS, and is determined by the amount of GHGs, entities, sectors, and locations that are included in the system. Lack of coverage can present issues in the effectiveness of an ETS, not only because lower coverage implies less emissions accounted for and therefore fewer reductions, but also because of an increased potential for carbon leakage. Carbon leakage is one of the key threats to the environmental integrity of ETSs, as carbon pricing is not currently implemented uniformly around the world. Leakage occurs when companies move their production or investments to another jurisdiction or another sector where the cost of emissions are lower (Kossoy *et al.*, 2015a). Several examples of leakage exist in current carbon markets around the world, mostly due to limited geographical extent, including California, RGGI, and Japan.

Unlike the centralized structure of the EU ETS, the WCI market comprises multiple independent trading programs in its member jurisdictions, with each state/province responsible for issuing emissions allowances according to its own mitigation targets (WCI, 2013). WCI is currently composed of five (British Columbia, California, Ontario, Quebec, Manitoba) participating jurisdictions (Klinsky, 2013; WCI, 2013), only three of which (California, Quebec, and Ontario) have successfully implemented ETSs to date (Government of Ontario, 2016a; Houle *et al.*, 2015). The limited geographical coverage of the WCI ETSs makes them susceptible to carbon leakage. California, in particular, suffers from cases of carbon leakage (Cullenward, 2014; Wara, 2014). Southern California Edison (a major electricity supplier to Southern California), for example, sold its interest in a coal-fired power station located in New Mexico to an Arizona utility provider prior to implementation of the ETS (Cullenward, 2010), resulting in significant leakage. State law requires that California's ETS minimizes leakage, however regulatory documents for the system allow resource shuffling, including 13 "safe harbor" exemptions allowing leakage of emissions to safe harbor coal power plants (Cullenward, 2014).

These features represent the main weakness of California's market, as resource shuffling and leakage produce a weak cap and minimize environmental benefits. California's market highlights the importance of regulating leakage, as well as the need for a more expansive regional or international market to initially avoid such leakage. California cannot specifically be blamed for its instances of carbon leakage, as a lack of a national carbon market (or more broadly, a global market) will inherently produce resource shuffling such that entities can remain competitive without needing to reduce emissions. Although this resource shuffling can undermine the emissions reductions that have occurred, the complementary environmental policies in place in California are unaffected by a weak market cap, and positive changes are therefore still occurring under its ETS (Cullenward, 2014).

Similarly, RGGI also struggles with instances of carbon leakage due to the nature of regional emissions reduction policies. It has been argued, however, that RGGI is a unique case in which unregulated regions have lower emissions intensive production and has prompted a shift towards cleaner production processes under regional regulation — creating a type of beneficial leakage (Fell and Maniloff, 2015). The Tokyo and Saitama ETSs are additional examples of small-scale ETSs that face the risk of carbon leakage (Roppongi *et al.*, 2016). This is the main concern remaining to be addressed in the Japanese systems, although the country has yet to reach a political consensus on the future of national climate policy and their INDC makes no mention of a national ETS to address this issue (UNFCCC, 2015).

One way to increase coverage of ETSs is through the linkage of systems. This solution is currently being pursued by the Swiss ETS, which, along with the potential for leakage, faces less cost-effective reduction potential, liquidity, price stability, and flexibility in achieving targets due to its small size (Sopher and Mansell, 2013). Discussion and technical negotiation between the European Commission and the government of Switzerland has led to an agreement (waiting to be ratified by both sides) for the Swiss ETS to link with the EU ETS (Federal Office for the Environment, 2016). The Swiss system was restructured in 2013 (after original implementation in 2008) to be similar in design to the EU ETS in order to facilitate linkage through mutually recognized emission allowances (Haites, 2016; Federal Office for the Environment, 2016). The thorough coverage of the EU ETS (including 31 participating countries) is a strong aspect of the system and allows it to avoid severe threats of carbon leakage (EC, 2016; Ellerman *et al.*, 2015).

Carbon leakage may also be addressed in theory through measures such as free allocation, border adjustments, and sectoral approaches, which all have the potential to address the primary cause of carbon leakage — industry competitiveness (Reinaud, 2009). Free allowance allocation has the ability to help mitigate costs to firms by compensating or protecting companies from the costs of carbon (Grubb and Neuhoff, 2006). Nevertheless, free allocation can still invoke costs to firms if the system cap is sufficiently stringent. Only emissions below the cap are in actuality freely allocated, while emissions at the margin of the cap are similar whether allowances are allocated freely or auctioned (Reinaud, 2008). Border adjustments could also be introduced on imports and exports of products from sectors susceptible to leakage, as has been suggested by the United States and European Commission to ensure that domestic emissions-intensive manufacturers are not placed at a disadvantage (Reinaud, 2009). Adjustments could occur in the form of a carbon tax on imported goods, which may address industry competitiveness for those participating in the market, and could further encourage exporters to improve their emissions intensity through lower border adjustments on their products (Reinaud, 2009).

A potential solution specifically designed to address sectoral leakage is the use of a carbon tax in sectors that are challenging to regulate through emissions trading. Fifteen countries have implemented or passed legislation for a carbon tax (Kossoy *et al.*, 2015b), and these taxes can be combined with other carbon policies, such as an ETS to further emissions reductions (Sumner *et al.*, 2011). Since emissions trading is more difficult to implement in sectors without point sources (e.g. transportation), as it is difficult to measure emissions at the source-level (Zhang and Wang, 2002), a carbon tax can be used in conjunction with an ETS and other carbon policies to cover emissions in those sectors.

For example, a carbon tax in France and Portugal is applicable only to specific sectors not included in the EU ETS (Kossoy *et al.*, 2015b; Sumner *et al.*, 2011). Norway's carbon tax covers 68% of emissions, while the EU ETS covers the remaining 35–40%, and Sweden uses a carbon tax to address the energy and transport sectors, but relies on other strategies such as the EU ETS to reduce emissions in other sectors (Sumner *et al.*, 2011). This complementary use of a carbon tax and emissions trading is increasingly common, with a combination of features from both instruments effectively restricting a larger portion of GHG emissions and avoiding leakage to other sectors of the economy (Kossoy *et al.*, 2015b; Sumner *et al.*, 2011).

3.4 Offsetting

Another important component of an ETS is its regulations for the offsetting of emissions reductions using offset credits. Offsetting refers to a unit of CO_2e that is reduced, sequestered, or avoided in one location to compensate for emissions occurring elsewhere. Some carbon markets allow industries to purchase offset credits from certified offset projects (such as energy efficiency projects, fuel switching projects, renewable energy projects, bio-sequestration through forestry and agricultural management practices, etc.) that can be used to cancel out their own emissions and help meet reduction targets (Carbon Offset Research & Education (CORE), 2011; Kill *et al.*, 2010). Theoretically, allowing for a portion of reductions to be offset allows for flexibility in the ETS without compromising environmental benefits, but the availability of cheap international offset credits has been shown to threaten carbon price stability, and poor regulation and MRV of offset projects can undermine the environmental intentions of the system (Kollmuss *et al.*, 2015).

The Chicago Climate Exchange (CCX) and the New Zealand ETS provide two examples of poor offset regulations, which ultimately led to a low carbon price. CCX is an example of a carbon market created predominately by private entities with participation from both large and small companies. It was created as a formal but voluntary market for firms to verifiably reduce their GHG emissions in preparation for anticipated future mandatory legislation (Gans and Hintermann, 2013). It began operating in 2003 but was discontinued at the end of 2010 due to a collapse in the exchange price of Carbon Financial Instruments (CFIs) (CORE, 2011; Gans and Hintermann, 2013). The exchange price decreased to $0.05 per CFI due to the large number of credits available from offset projects (CORE 2011). Failure of the CCX led to questioning of the legitimacy of the system and its reporting and verification of offsets, emphasizing the importance of strict regulation of offset credits.

The New Zealand ETS has also experienced issues with the use of offset credits. The effectiveness of the system has been a topic of debate as the New Zealand Unit (NZU) price has been low, not only due to a liberal allocation policy, but also due to the previously unlimited permitted use of international offset credits (Diaz-Rainey and Tulloch, 2015). Unlike other systems, the NZ ETS previously had no quantitative restriction on the amount of CERs, or international carbon credits issued by the Clean Development Mechanism (CDM) (Richter and Mundaca, 2013) — a market-based mechanism implemented by the KP in 2005. This is generally thought to be the reason for the price decline in its domestic offset units, as the oversupply in emissions credits with a lower cost than domestic NZUs flooded the market and reduced the price of NZUs. While New Zealand no longer allows international credits to be traded within its ETS (as of June 2015), the government has stated that it will reassess the use of international credits once international market conditions are more in line with its domestic situation (Kossoy *et al.*, 2015a), with international market access remaining a priority in New Zealand's INDC (ICAP, 2016; UNFCCC, 2015).

Emissions reductions through the CDM have also been highly criticized (Gavard *et al.*, 2013), with over-reporting and over-crediting of CERs leading to concerns about the validity and reliability of these credits (Rahman and Kirkman, 2015). This could be a great threat to the environmental integrity of ETSs that allow for this offset, as the incorporation into the EU ETS, for example, is estimated to have undermined the EU's reduction target by about 400 million tCO_2e (Kollmuss *et al.*, 2015).

One solution to these issues regarding offset credits, as more recently implemented by New Zealand, is to allow the use of only domestic offset credits, in which case the flexibility of offsetting remains a while the threat of cheap international credits is avoided. This solution has also been integrated into the Chinese pilot ETSs, where enterprises in the pilot systems can use Chinese Certified Emission Reductions (CCERs) from domestic offset projects to offset up to 5–10% of their compliance obligation (Liu *et al.*, 2015; Wang, 2016). All Chinese pilot systems are restricted to using domestic offset projects, with many placing further restrictions on offsetting (Liu *et al.*, 2015; Wang, 2016). In Beijing, for example, 5% of annual compliance obligations can be offset using CCERs from domestic projects, but 50% must come from projects within Beijing (ICAP, 2016). Similarly, Hubei requires that 10% of annual compliance obligations can be met using CCERs, but those credits must come from the province of Hubei or provinces that have signed agreements with Hubei (ICAP, 2016).

Offset regulations can be improved by allowing but limiting the percentage of reductions that can be offset internationally. This is the case in many currently operating ETSs, including California and Quebec, where emissions reductions can be offset internationally, but only up to 8%. Another approach may be to restrict international offsets according to quality and quantity, as the EU ETS has done in Phase III. Qualitative restrictions on offsetting projects have been put in place, wherein nuclear energy projects, afforestation or reforestation activities, and projects involving the destruction of industrial gases are no longer accepted, hydroelectric projects exceeding 20 MW are accepted under certain conditions, and the use of new credits/CERs are prohibited unless registered in one of the least developed countries (EC, 2017). Further, the third phase of the EU ETS has imposed quantitative restrictions through a specified maximum limit up to which participating entities may use eligible international credits (EC, 2017).

4 Issues and Challenges in ETS Regulation

4.1 Monitoring, Reporting, and Verification

The design elements discussed earlier are only effective if proper MRV allows them to be followed and complied with correctly. Effective implementation of an ETS requires rigorous monitoring of emissions and verification of reported reductions, which in turn requires availability of accurate monitoring and measurement equipment (Kill *et al.*, 2010). Lack of transparency in MRV can lead to under-reported emissions, over-reported offsets or creation of income for certain stakeholders, threatening the integrity of any ETS (Haites, 2016; Kossoy *et al.*, 2015a). There are many cases of poor MRV in current ETSs, one of which led to the dissolution of the Pacific Carbon Trust (PCT), an ETS in implementation from 2010 to 2014 in British Columbia (BC), Canada (Pacific Carbon Trust (PCT), 2014; 2016).

The goal of the PCT was to help develop a low-carbon economy and a carbon-neutral public sector in BC (PCT, 2014). As such, public sector organizations were required to make offset payments through the PCT for their emissions at a fee of \$25 tCO_2e, in addition to BC's carbon tax (Lee, 2011). The PCT claims to have reduced BC emissions by 3,014,666 tons between 2010 and 2013 (PCT, 2016). It was dissolved in November 2013 (PCT, 2014; 2016) due to public concern about the funds being taken from public services, as well as questions about the credibility of some PCT offsets (Doyle, 2013; Harrison, 2013). Although PCT funds were taken from the public sector, particularly affecting education budgets, mitigation projects mainly occurred in the private sector, disproportionately catering to the affluent (Harrison, 2013).

The other main criticism of the PCT that led to its failure was the use of questionable offsets and insufficient reporting of purchases (Doyle, 2013; Lesiuk *et al.*, 2011). For example, the Nature Conservancy of Canada received \$4.5 million in offset credits for preserving trees that were not likely to be logged, regardless of PCT funding, and fuel-switching projects that had been approved before establishment of PCT also received funding (Doyle, 2013). Additionally, there was a lack of criteria for evaluating whether sufficient actions to reduce emissions were being taken by PCT (Doyle, 2013). Collectively, the combination of these factors caused the public to question the integrity and effectiveness of this system, leading to its eventual dissolution.

Similarly, poor MRV is currently occurring in the seven pilot ETSs in China, which suffer from a lenient design and poor information transparency (Peng *et al.*, 2015; Xiong *et al.*, 2016). Issues faced by these systems include inaccuracy in quota allocation due to inaccurate or nonexistent historical records, as well as legislation that is lagging behind in terms of emission rights, trading rules, monitoring, collection of emissions data, and verification (Liu *et al.*, 2015). China's inadequate MRV will become particularly evident when transitioning into a national ETS in the coming years, as a unified emission management institution will be necessary to regulate the system (Swartz, 2016).

China's carbon market is currently managed by the National Development and Reform Commission (NDRC), which is focused on the country's participation in the CDM, with little experience that would enable it to manage a national system (Liu *et al.*, 2015). This inexperience and the large size of the system will lead to significant challenges in national ETS development, such as ensuring compliance and enforcement, applying uniform rules for MRV across the country, and establishing a representative carbon price to trade in the international market (Liu *et al.*, 2015; Swartz, 2016). National legislation that focuses on climate change mitigation needs to be developed as soon as possible, and transparent, independent reporting of emissions need to be prioritized (Zhang *et al.*, 2014).

Nonetheless, different systems have adopted various methods of MRV, with successful examples demonstrating transparent and straightforward guidelines as well as consistent enforcement, some using carbon taxes. Despite issues such as conflicts of interest with third party verifiers, California provides a positive example of transparent, detailed, openly available MRV guidelines and instructions. The California ETS is operated by the California Air Resources Board (ARB), which regulates all aspects of the system, including the distribution of allowances and offset credits (Wang and Wu, 2013). California's ETS currently allows domestic offset projects (forest, urban forest, livestock, ozone depleting substances, mine methane capture, and rice cultivation projects) to offset up to 8% of a regulated facility's required emissions reductions (ICAP, 2016; Lueders *et al.*, 2014). As of June 2016, ARB had issued 14,791,335 compliance offset credits and 8,338,280 early action project offset credits (ARB, 2016).

In California, eligible forest carbon offset projects may include reforestation, improved forest management and avoiding conversion of timberland to nonforest use, but must follow ARB's Compliance Offset Protocol for US Forest Projects (ARB, 2015; Forest Carbon Partners (FCP), 2016). These projects adhere to strict guidelines and rules regarding reference levels (BAU baseline must be modeled over a 100-year period and the crediting period must be 25 years), additionality (demonstrations of additionality including regulatory surplus tests, legal requirements tests, and performance tests), leakage (mandatory accounting of secondary effects including activity shifting), permanence (monitoring and verification activities maintained for at least 125 years), environmental requirements (projects must maintain structural elements, age class diversity, and carbon in live trees), and monitoring and reporting (complete inventory of carbon stocks reported each year) (ARB, 2015).

Other examples of successful MRV procedures can be found in the European and Japanese ETSs. The EU ETS requires that each member submit an annual emissions report that has been checked by an authorized verifier in order to ensure compliance (EC, 2013). The centralized regulatory body of the EU ETS ensures that the cap is complied with and no entities are underreporting emissions or over reporting offsets (Kill *et al.*, 2016). Similarly, the honesty, transparency, and consistent enforcement of effective monitoring is a fundamental factor in the high compliance and success of the Japanese systems, as MRV in Tokyo and Saitama follows strict and reliable procedures that include external verification (Roppongi *et al.*, 2016; Rudolph and Kawakatsu, 2012).

Apart from these examples of success, it is important to note that MRV is a very complex aspect of any ETS and can be challenging to implement, depending on the specific characteristics of the system and the resources available. As such, another method that has been used to address the complexity in MRV is the use of a carbon tax on the purchase or use of fuels for sectors that are particularly challenging to regulate through an ETS, as a carbon tax is naturally more administratively simple to implement and to follow (Wittneben, 2009). Examples of this methodology, as discussed previously, include Norway, Sweden, France, and Portugal (Kossoy *et al.*, 2015b; Sumner *et al.*, 2011). The complementary use of a carbon tax and emissions trading may be a promising means to price carbon in a way that can be controlled through MRV (Kossoy *et al.*, 2015b; Sumner *et al.*, 2011).

4.2 Clear Commitment and Ambition

In order to implement and regulate any of the components of an ETS discussed earlier, clear commitment and ambition is critical. Poor, inconsistent commitment and ambition can lead to a weak system, as demonstrated by attempted ETSs in Australia and Kazakhstan. In Australia, inconsistent commitment and unclear ambition has led to a lack of growth and development in climate policy over time (Chan, 2015), while in Kazakhstan, new government leadership has led to suspension of an ETS, delaying any improvements in the system and the ecological benefits it provides (Climate Policy Observer, 2016).

Climate policy in Australia has undergone many modifications, in part due to shifts in government power. In 2011 the national ETS failed to pass through government (Australian Government, 2014), and instead a carbon tax was implemented in July 2012, covering 60% of Australia's GHG emissions from electricity generation, industry, fuel distributors, industrial processes, mines, and waste (Chan, 2015; Jotzo, 2012; Robson, 2014). While the Australian carbon tax was designed and implemented to be eventually converted into an ETS (Robson, 2014), the tax was repealed by a newly elected government in June 2014, making Australia the only developed nation at the time to reverse action on climate change (Chan, 2015). Following the election of a new Prime Minister in 2015, an Emissions Reduction Fund (ERF) was introduced as part of the new government's Direct Action Plan (DAP) (Australian Government, 2014). While the ERF is not considered an ETS, it is similarly a market-based mechanism that prices carbon and creates a national market for Australian Carbon Credits Units (ACCUs) (Australian Government, 2014). The ERF is a voluntary scheme that allows for offsetting, which works alongside existing supplementary low carbon policies and standards (Australian Government, 2014). Australia has had plans in the past to implement a national ETS with the hopes of eventually linking it to the European Union: however plans to implement a national system appear to be on hold.

Although Australia is making progress towards policies to help meet reduction goals, changes in leadership have delayed progress and cost the country critical time for reducing emissions and developing an effective trading system. Poor planning and implementation, lack of public and political support, and strong opposition from industry led to continued political uncertainty, little credibility, and ultimately to the repeal of the tax (Jotzo, 2012; Robson, 2014). Collectively, these features provide a demonstration of poor commitment and ambition starting from implementation (Taylor and Hoyle, 2014) and emphasize the importance of facilitating sufficient public, political, and industry support to implement a successful system.

The Kazakhstan ETS is currently facing a similar issue with inconsistencies in commitment, ambition, and leadership. This system was launched in January 2013 (ICAP, 2016; Swartz and Upston-Hooper, 2013), but with a new incoming government in 2016, Phase III has been suspended for 2 years (until 2018) by Vice Energy Minister Asset Magauov (Climate Policy Observer, 2016). Details of the suspension are not yet public, but it is likely a response to industry protests about the strict requirements and weak legal foundation of the system under the current national economy (Climate Policy Observer, 2016).

Effective commitment and clear ambition require several important characteristics, including political, public, and industry support of decisions, strict enforcement of compliance and rules, and adaptability. In some cases, ensuring success of an ETS requires tradeoffs, as in South Korea, where cooperation with industry required leadership to make compromises in the design of its ETS (Heo, 2015). South Korea's ETS faced extreme confrontation and criticism prior to implementation in January 2015, with many stakeholders arguing that the system would impose a burden on the national economy (Heo, 2015; Sopher and Mansell, 2014). One key compromise upon launch of this ETS was the agreement to 100% free allocation of allowances in the first phase (Heo, 2015; Sopher and Mansell, 2014). The system is too young to fully understand the impacts of this decision, but it is meant to help leadership gain support for the system, which can then be modified over time to be more conducive to environmental benefits. The California and Quebec systems have likewise fostered support and stakeholder involvement through the early announcement of auctions and the organization of resources for participants, such as training sessions and assistance centers.

A similar approach to clear commitment and ambition is taken in the Japanese systems, which provide an ideal example of strict regulation that demands compliance from all parties. The effectiveness of the ETSs in Tokyo and Saitama can be largely attributed to leadership and administrative capacity, which includes stakeholder involvement in policy formulation and implementation, availability of data to support policy decisions, and gradual implementation to foster support for leadership decisions (Roppongi *et al.*, 2016; Rudolph and Kawakatsu, 2012). The TMG ETS, for example, was implemented gradually over three main phases, starting in 2000, before the first compliance period in 2010, and used a decade-long data set of industrial activities and existing reduction plans to create a detailed policy design targeted to local conditions in

Tokyo, which were fundamental ways to induce collective action and gain stakeholder acceptance of the ETS (Roppongi *et al.*, 2016).

Another indication of effective commitment and clear ambition is the ability to identify issues and adapt over time in order to address the concerns of participating entities. As the longest running and oldest cap and trade system, the EU ETS is an example of strong leadership that has learned from its mistakes and made necessary changes over time (European Commission, 2016; EC, 2015). Over its three phases, the EU ETS has been altered to address various concerns, such as including aviation (Haites, 2016; Kopsch, 2012), extending the trading period to allow for more predictability and encourage longer-term investment (Papageorgiou *et al.*, 2015), and switching from an inefficient and ineffective decentralized structure with multiple National Allocation Plans to a centralized allocation system and system-wide cap (Ellerman *et al.*, 2015; Kill *et al.*, 2010).

Additional actions are currently being taken to address remaining instability in this market, such as decreasing the cap by 2.21% per year starting in 2021 (EC, 2016), phasing out the grandfathering of emission credits completely by 2027, adopting a Market Stability Reserve to control allowance availability after 2020 (Ellerman *et al.*, 2015), and requiring that emissions reductions be achieved through domestic actions alone starting in 2020 (Hawkins and Jegou, 2014). The ability to make necessary changes over time demonstrates strong leadership and regulatory control, and has played an important role in the consistent advancement and improvement of the EU system.

5 Issues and Challenges in International Linkage

The current status of carbon markets around the world is fragmented and inconsistent, with significantly varying prices of carbon between jurisdictions (Kossoy *et al.*, 2015a). This fragmentation can undermine the positive environmental intentions of ETSs by leading to issues such as carbon leakage, indicating a need for international cooperation (Fell and Maniloff, 2015; Liu and Wei, 2014). There are many incentives for the development of an international carbon market; it would allow for increased economic efficiency of emissions reductions, more stability in prices, consistency between emissions markets for international business partners, greater flexibility and liquidity in meeting reduction targets, less market power for large participants, lower transaction costs, and less risk of carbon leakage (Carbone *et al.*, 2009; Haites, 2016; Hawkins and Jegou, 2014; Johannsdottir and McInerney, 2016; Kill *et al.*, 2010; Kossoy *et al.*, 2015a; Ranson and Stavins, 2016). There is also potential for global market linkage to minimize the development gap and foster sustainable development by encouraging low-carbon growth in poorer countries (Kossoy *et al.*, 2015a).

5.1 International Linkage

Although many jurisdictions with existing cap-and-trade policies have expressed interest in international collaboration, developing an effective global carbon market design has so far proven to be very challenging (Ranson and Stavins, 2015), as international markets are harder to regulate and can lead to a loss of regional control (Haites, 2016; Hawkins and Jegou, 2014; Kill *et al.*, 2010). Potential issues with international linkage come in three main forms: leakage and compliance issues due to weak regulation and MRV; loss of competitiveness of domestic carbon units or offset projects; and finally, a decrease in carbon price due to cheaper permits available internationally (Alexeeva and Anger, 2015; Liu and Wei, 2014). All of these cases can lead to an increase, as opposed to a decrease, in emissions, if not adequately addressed.

Examples of previous attempts to develop international markets are the two market-based mechanisms implemented by the KP in 2005: the Clean Development Mechanism (CDM) and Joint Implementation (JI) (UNFCCC, 2014, 2016). These mechanisms are still relevant and frequently used, particularly for countries that have entered into a second commitment period (2013–2020) under the KP (UNFCCC, 2016). CDM regulates offset projects in countries that do not have emissions targets (Non-Annex I) to help Annex I countries meet their KP targets by reducing emissions in developing countries and earning certified emissions reduction (CER) credits (Kill *et al.*, 2010; Rahman and Kirkman, 2015). In the JI mechanism, offset credits are generated by offset projects within the capped (Annex I) country (Kill *et al.*, 2010). Under this mechanism, ERUs can be earned from an emissions reduction by source or emissions removal by sink project in a capped country and can be used towards meeting KP targets (Kill *et al.*, 2010).

Although they provide flexibility for countries to meet their targets, and in the case of CDM, can act to stimulate sustainable development (Rahman and Kirkman, 2015; UNFCCC, 2016), research has shown that these mechanisms have led to an increase in emissions above KP targets (Kollmuss *et al.*, 2015). This is not necessarily due to the design of these mechanisms, but instead to poor regulation and MRV, as offsets reported from nonadditional or over-credited projects have led to an increase in global emissions, threatening the environmental effectiveness of these systems (Kollmuss *et al.*, 2015). JI, for example, is estimated to have led to an additional 600 million tCO_2e being emitted than if emissions targets were met domestically (Kollmuss *et al.*, 2015) since an estimated 75% of reported ERUs do not represent additional emissions reductions.

Although legitimate barriers will challenge future international linkage and the pursuit of an international carbon market, countries and institutions have already begun to discuss potential solutions to many of these barriers. Article 6 of the Paris Agreement, for example, addresses two international market frameworks for international carbon trading to replace or at least improve the current systems: a framework for cooperative approaches to allow for linkage of current ETSs, and a new market mechanism (NMM) framework to contribute to the mitigation of GHG emissions and support sustainable development (UNFCCC, 2015). Details of these frameworks have yet to be disclosed, but the NMM is proposed as a more holistic market approach that will complement CDM and JI (UNFCCC, 2015) and will involve non-Annex I countries beyond their current participation in CDM (Gavard *et al.*, 2013). These frameworks, although currently limited in detail, imply the importance of carbon trading in the future of international climate policy.

There are four main scenarios for constructing a global carbon market: a top-down global trading system based on an international treaty; formal linkage of domestic ETSs to construct an international market from the bottom up; indirect linkage of national and regional ETSs through common use of credits such as done in the CDM; or a mixture between these approaches, containing elements of all three (Flachsland *et al.*, 2008; Rudolph and Kawakatsu, 2012). As with CDM and JI, the NMM proposed by the Paris Agreement represents an indirect linkage design. One potential structure for this mechanism discussed in the literature is sectoral trading, in which one economic sector of an Annex I country would be coupled with that of a Non-Annex I country (Gavard *et al.*, 2013). Adoption of this type of mechanism would require close regulation and careful design, including limits placed on the number of permits that can be traded between jurisdictions to avoid carbon leakage to the rest of the economy as a result of a reduction in carbon prices in one sector (Gavard *et al.*, 2013).

A more promising option for international market development is the bottom-up linkage of smaller, established ETSs. Top-down global climate negotiations have progressed slowly and as a result, the bottom-up mitigation efforts emerging in current climate policy, recently proposed INDCs, and the growing network of decentralized, direct market linkages may be a more practical way to coordinate climate action (Liu and Wei, 2014; Ranson and Stavins, 2016; Rudolph and Kawakatsu, 2012). Many models of global carbon market development currently explored in the literature follow this bottom-up approach, which involves development of national or regional ETSs with their own caps, followed by market linkage, cap coordination and eventually a global ETS where all emitters coordinate to achieve global reductions in emissions (Heitzig, 2012).

Pre-existing linkages between ETSs are already a part of the 'international policy structure' for global climate change mitigation strategies (Jaffe and Stavins, 2008) and provide hope for the potential of international market linkage. There are many successful examples of this type of linkage, including the unilateral linkage between the Tokyo ETS and Saitama ETS, as well as between the California ETS and Quebec ETS (with the Ontario ETS scheduled to link in 2018) (ICAP, 2016). The California system is much larger than Quebec's, with a cap of 334.2 million tCO_2e in 2020 compared to 54.7 million in Quebec; nonetheless, these markets provide a successful example of a cross-border linkage, including interchangeable emissions allowances, coordination of regulatory provisions, offset protocols and joint auctions, and mutual recognition of compliance instruments (Haites, 2016). RGGI also acts as a successful example of cooperation between multiple jurisdictions within a market to lower compliance costs and generate economic benefits (Hibbard *et al.*, 2015). The establishment of RGGI, along with the California and Quebec ETSs, is a meaningful step towards carbon market development in the USA and Canada, both of which currently lack a national pricing instrument (C2ES, 2016; Kossoy *et al.*, 2015a).

Europe is another example of a successful linkage at a larger scale, and the EU ETS provides a particularly valuable example for the development of an international trading scheme, demonstrating cooperation between 31 countries and exhibiting the successful linkage of initially independent ETSs. The United Kingdom Emissions Trading Group (UK ETG), for example, began in 2002 as a separate, voluntary ETS (Christiansen and Wettestad, 2003; Ellerman and Buchner, 2007; Smith and Swierzbinski, 2007) before changing in 2007 (by making compliance mandatory and adhering to the targets set by the European Union) to accommodate entry into the second compliance period of the EU-wide scheme (Christiansen and Wettestad, 2003; Environmental Defense Fund (EDF), 2013). The European Commission continues to actively pursue internationalization of its carbon market (Alexeeva and Anger, 2015), and this type of linkage may occur again, since recent discussions and technical negotiations with the government of Switzerland have led to an agreement (waiting to be ratified by both sides) for the Swiss ETS to be linked to the EU ETS (Federal Office for the Environment, 2016).

In addition to the EU ETS, a Memorandum of Understanding (MoU) was signed in 2014 between Mexico and California regarding climate change and the environment, and more recently between Ontario and Quebec (State of California, 2014; Government of Ontario, 2016), establishing coordination across areas such as intellectual property and the development of domestic markets (World Bank and Group, 2016). Instances of bilateral assistance also exist; for example, the European Union is providing technical assistance to China for the development of its future national ETS (European Commissions, 2015), as well as to the Republic of Korea (World Bank and Group, 2016).

6 Lessons Learned and Recommendations

Successful implementation of market-based climate policy instruments, whether cap-and-trade or a carbon tax, require a high degree of commitment to the importance of climate change and confidence in the capacity of government to participate effectively in the market (Houle *et al.*, 2015). Future development of national or regional systems need to consider the experiences of previous ETSs in order to avoid repeating structural and design flaws that could lead to failure of the system.

The importance of politics, leadership, and regulation of these systems should not be underestimated (Kossoy *et al.*, 2015b).

Developing ETSs, including those of China and the Ukraine, should consider the seven factors discussed in this paper to ensure development of an effective system. Once an ETS is developed, international linkage should only be pursued if confident that the domestic or regional system has the economic and environmental integrity necessary to do so responsibly. China, as the largest currently developing market, is a particularly important example to address, as it is expected to expand the scope of global GHG emissions covered by similar schemes by as much as 16%, with an expected cap size of 4 billion tonnes — twice the size of the EU ETS and larger than all other existing carbon markets combined (Swartz, 2016). Due to its size, the success or failure of a national market in China could determine the fate of the international carbon trade.

Recommendations for the development of a national ETS in China include: ensuring that the goals of the system are in line with national climate change objectives, focusing on emissions reductions in the production sectors, taking into account unbalanced regional development, ensuring that transparent independent reporting of emissions is used, considering an absolute cap since it is key to the environmental integrity of the system, covering as many sectors as possible to ensure liquidity, establishing a strong compliance and enforcement plan, implementing policies to address the risk of carbon leakage, avoiding overlapping environmental policies in the country, increasing the amount of allowances that are auctioned to avoid entirely free allocation, and improving the timeliness and transparency of information including rules and regulations (Pang *et al.*, 2015; Peng *et al.*, 2015; Swartz, 2016; Xiong *et al.*, 2016; Zhang *et al.*, 2014). Due to the administrative challenge of coordinating such a large national ETS in China (Zhang *et al.*, 2014), a top-down, centrally controlled national market is recommended, as opposed to an attempted linkage of the seven existing pilot systems (Pang *et al.*, 2015). The issues revealed during the implementation of those seven systems should, however, be thoroughly assessed before launching a national carbon market (Peng *et al.*, 2015; Xiong *et al.*, 2016).

With regard to international market development, there is an apparent preference for linking ETSs as a climate mitigation policy, with many of the world's cap-and-trade systems already linked either directly or indirectly. This indicates market linkage is the direction large-scale climate policy has taken and as such, may be the most politically realistic mechanism for meeting reduction targets in a cost-effective manner (Carbone *et al.*, 2009; Ranson and Stavins, 2016). The transition to an international carbon market will require cooperation at all levels and a great deal of compromise between policy makers, but could provide benefits to all countries if executed wisely (Hawkins and Jegou, 2014; Kossoy *et al.*, 2015a). A successful international market will require clear ambition of INDCs that have been converted into multi-year emissions targets, as well as stringent and agreed upon international accounting rules (Kollmuss *et al.*, 2015). Whichever mechanism is implemented, the Paris Agreement must learn from the mistakes made by the CDM and JI and remember the following: it is essential for crediting mechanisms to adopt fully transparent procedures with publicly available documentation, only internationally accepted methodologies should be eligible for use, auditors should be fully accountable for their actions and report to the authority regulating the mechanism, retroactive crediting should not be allowed, and investors must have reasonable certainty from the beginning that their projects will or will not be approved in order to avoid nonadditional projects being favored (Kollmuss *et al.*, 2015).

Despite recent emphasis on the development of an international climate agreement, current trends in carbon market development point to the emergence of a decentralized, bottom-up international system as the best solution moving forward. Bottom-up linkage is much simpler to implement if system designs are similar (or virtually identical), such that existing trading systems should become compatible and linkable, with similar methodology, tools, standards, and indicators (Carbone *et al.*, 2009; Haites, 2016; Johannsdottir and McInerney, 2016; Kill *et al.*, 2010; Ranson and Stavins, 2016). There are a few major elements of ETSs that should be coordinated to different degrees to facilitate linkage. Elements that should be identical to one another for simple and effective linkage include compliance mechanisms, price containment measures, banking and borrowing rules, and offset mechanisms. Cap setting and allowance allocation should be mutually recognizable between linked systems, and MRV standards and technical registry standards would be preferably identical, while coverage and scope do not necessarily require coordination between systems (Pang *et al.*, 2015).

7 Conclusion

It is widely considered essential to limit warming to 1.5°C above preindustrial levels, a major outcome of the Paris Agreement, and the cost of doing so will be reduced through global cooperation (Olsson *et al.*, 2016). In order for this goal to be achieved, the emissions reduction ambitions of countries must increase substantially and the system that enforces these reductions must be fair and forceful. Carbon markets could be a promising way to facilitate cooperation and achieve this goal, as long as they are regulated with transparency, integrity, and positive environmental intentions. The most important requirement of any successful carbon market is that the price of carbon is sufficiently high and consistent to achieve intended environmental benefits, and that prices are not set according to what is feasible in the market.

As such, there are seven main factors to consider for successful implementation of an ETS: a cap that produces reasonable prices and emissions reductions; permits that are allocated in an equitable way with a balance between free allocation and auctioning to create support for the system; trading guidelines that allow flexibility but avoid carbon leakage; careful regulation of international offsets that ensures environmental integrity is not compromised; high compliance achieved by ensuring a stable system with clear commitment and ambition, and strong leadership that allows industry to reliably meet their reduction goals; monitoring of emissions that is transparent and continuous; and finally, careful collaboration that maintains the integrity of each system being linked. While this review has analyzed an extensive literature and widespread empirical experience to identify valuable lessons and recommend key attributes for successful ETS implementation in the future, the full range of complexity within ETSs should not be underestimated, and contextual differences across systems should be further considered, as successful features in one system may not be applicable in another. The use and design of these markets is rapidly evolving with implementation of the Paris Agreement and with increased international interest in cooperative climate action. Such market-based instruments are emerging as an important component of the future climate change strategy and can be a promising means to address the significant and dynamic challenges of a changing global climate.

References

Air Resources Board. 2016. "Cap-and-Trade Program". Available at: http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm (retrieved June 30, 2016).

Alexeeva, V. and N. Anger. 2015. "The Globalization of the Carbon Market: Welfare and Competitiveness Effects of Linking Emissions Trading Schemes". *Mitigation and Adaptation Strategies for Global Change*: 1–26.

Australian Government. 2014. "Emissions Reduction Fund White Paper. Commonwealth of Australia 2014". Available at: http://www.environment.gov.au/system/files/resources/1f98a924-5946-404c-9510-d440304280f1/files/emissions-reduction-fund-white-paper_0.pdf (accessed March 31, 2016).

Carbon Offset Research and Education (CORE). 2011. "Chicago Climate Exchange". Stockholm Environment Institute and Greenhouse Gas Management Institute. Available at: http://co2offsetresearch.org/policy/CCX.html (accessed on June 27, 2016).

Carbone, J. C., C. Helm, and T. F. Rutherford. 2009. "The Case for International Emission Trade in the Absence of Cooperative Climate Policy". *Journal of Environmental Economics and Management.* 58(3): 266–80.

Center for Climate and Energy Solutions (C2ES). 2016. "Regional Greenhouse Gas Initiative". Available at: http://www.c2es.org/us-states-regions/regional-climate-initiatives/rggi (accessed on June 27, 2016).

Chan, K. 2015. "Don't Forget the Weather in the Axing of the Carbon Tax in Australia". *Carbon Management.* 6(1–2): 63–8.

Christiansen, A. C. and J. Wettestad. 2003. "The EU as a Frontrunner on Greenhouse Gas Emissions Trading: How Did it Happen and Will the EU Succeed?" *Climate Policy.* 3(1): 3–18.

Clarke, L., K. Jiang, K. Akimoto, M. Babiker, G. Blanford, K. Fisher-Vanden, J.-C. Hourcade, V. Krey, E. Kriegler, A. Loschel, D. McCollum, S. Paltsev, S. Rose, P. R. Shukla, M. Tavoni, B. van der Zwaan, and D. P. van Vuuren. 2014. "Assessing Transformation Pathways". Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014; IEA, World Energy Outlook.

Climate Policy Observer. 2016. "Kazakhstan ETS to be Suspended Until 2018". International Center for Climate Governance, Venice, Italy. Available at: http://climateobserver.org/9443-2/ (accessed April 1, 2016).

Cullenward, D. 2014. "How California's Carbon Market Actually Works". *Bulletin of the Atomic Scientists*. 70(5): 35–44. DOI: 10.1177/0096340214546834.

Dahan, L., M. Afriat, K. Rittenhouse, P. Sopher, D. Francis, K. Kouchakji, and K. Sullivan. 2015. "Quebec: An Emissions Trading Case Study". Environmental Defense Fund, CDC Climate Research, IETA, 15 p. Available at: http://www.cdcclimat.com/IMG/pdf/quebec-ets-case-study-edf-ieta-cdcclimat_28042015-5.pdf.

Department and Energy and Climate Change. 2015. "Emissions and Emissions Trading: Participating in the EU ETS". Available at: https://www.gov.uk/guidance/participating-in-the-eu-ets (accessed March 16, 2016).

Diaz-Rainey, I. and D. J. Tulloch. 2015. "New Zealand's Emission Trading Scheme: A Financial Perspective".

Doda, B. 2016. "How to Price Carbon in Good Times... and Bad!" *Wiley Interdisciplinary Reviews: Climate Change*. 7(1): 135–44.

Doyle, J. 2013. "An Audit of Carbon Neutral Government". Report 14. Office of the Auditor General of British Columbia. Available at: http://www.bcauditor.com/sites/default/files/publications/2013/report_14/report/OAG%20Carbon%20Neutral.pdf.

Duan, M., T. Pang, and X. Zhang. 2014. "Review of Carbon Emissions Trading Pilots in China". *Energy & Environment*. 25(3–4): 527–50.

Ellerman, A. D. and B. K. Buchner. 2007. "The European Union Emissions Trading Scheme: Origins, Allocation, and Early Results". *Review of Environmental Economics and Policy*. 1(1): 66–87.

Ellerman, A. D., C. Marcantonini, and A. Zaklan. 2015. "The European Union Emissions Trading System: Ten Years and Counting". *Review of Environmental Economics and Policy*. rev014.

Environmental Defense Fund (EDF). 2013. "The World's Carbon Markets: A Case Study Guide to Emissions Trading". Available at: http://www.ieta.org/worldscarbonmarkets (retrieved May 16, 2016).

European Commission. 2013. "The EU Emissions Trading System (EU ETS)". Climate Action. Available at: http://ec.europa.eu/clima/publications/docs/factsheet_ets_2013_en.pdf (retrieved April 4, 2016).

European Commission. 2016. "The EU Emissions Trading System". Available at: http://ec.europa.eu/clima/policies/ets/index_en.htm (accessed March 16, 2016).

European Commission. 2017. "Use of International Credits". Available at: https://ec.europa.eu/clima/policies/ets/credits_en (accessed April 20, 2017).

European Commissions. 2015. "EU-China Joint Statement on Climate Change". Available at: http://www.consilium.europa.eu/en/meetings/international-summit/2015/06/150629-eu-china-joint-statement-on-climate-change/ (Accessed April 24, 2017).

Federal Office for the Environment (FOEN). Swiss Confederation. 2016. "Linking the Swiss and EU Emissions Trading Schemes". Available at: http://www.bafu.admin.ch/klima/13877/14510/14882/index.html?lang=en (accessed March 29, 2016).

Fell, H. and P. Maniloff. 2015. *Beneficial Leakage: The Effect of the Regional Greenhouse Gas Initiative on Aggregate Emissions (No. 2015–06)*. Colorado School of Mines, Division of Economics and Business.

Flachsland, C., O. Edenhofer, M. Jakob, and J. Steckel. 2008. *Developing the International Carbon Market: Linking Options for the EU ETS*. Potsdam Institute for Climate Impact Research.

Forest Carbon Partners. 2016. "Projects". Available at: http://www.forestcarbonpartners.com (accessed June 19, 2016).

Gans, W. and B. Hintermann. 2013. "Market Effects of Voluntary Climate Action by Firms: Evidence From the Chicago Climate Exchange". *Environmental and Resource Economics*. 55(2): 291–308. DOI: 10.1007/s10640-012-9626-7.

Gavard, C., N. Winchester, and S. Paltsev. 2013. *Limited Sectoral Trading between the EU ETS and China*. MIT Joint Program.

Government of Ontario. 2016a. "Cap and Trade in Ontario". Retrieved from: https://www.ontario.ca/page/cap-and-trade-ontario?_ga=1.255640456.1824590736.1492545881.

Government of Ontario. 2016b. "Joint Declaration Between the Ministry of Environment and Natural Resources of the United Mexican States, the Government of Ontario, and the Gouvernement Du Québec". Available at: https://news.ontario.ca/opo/en/2016/08/joint-declaration-between-the-ministry-of-environmentand-natural-resources-of-the-united-mexican-st.html (accessed April 24, 2017).

Grubb, M. and K. Neuhoff. 2006. "Allocation and Competitiveness in the EU Emissions Trading Scheme: Policy Overview". *Climate Policy*. 6(1): 7–30.

Haites, E. 2016. "Experience with Linking Greenhouse Gas Emissions Trading Systems". *Wiley Interdisciplinary Reviews: Energy and Environment*. 5: 246–60. DOI: 10.1002/wene.191.

Harrison, K. 2013. "The Political Economy of British Columbia's Carbon Tax". OECD Environment Working Papers, No. 63, OECD Publishing. http://dx.doi.org/10.1787/5k3z04gkkhkg-en.

Hawkins, S. and I. Jegou. 2014. *Linking Emissions Trading Schemes: Considerations and Recommendations for a Joint EU–Korean Carbon Market*. Geneva, Switzerland: International Centre for Trade and Sustainable Development, www.ictsd.org.

Heitzig, J. 2012. "Bottom-Up Strategic Linking of Carbon Markets: Which Climate Coalitions Would Farsighted Players Form?" Available at: SSRN 2119219.

Helm, C. 2003. "International Emissions Trading with Endogenous Allowance Choices". *Journal of Public Economics*. 87(12): 2737–47.

Heo, I. 2015. "Managing Policy Dilemmas in South Korea: The Case of the Emissions Trading Scheme". *Asian Studies Review*. 39(3): 447–65.

Hibbard, P. J., A. M. Okie, S. F. Tierney, and P. G. Darling. 2015. "The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States".

Houle, D., E. Lachapelle, and M. Purdon. 2015. "Comparative Politics of Sub-Federal Cap-and-Trade: Implementing the Western Climate Initiative". *Global Environmental Politics*.

ICAP. 2016. "Emissions Trading Worldwide: Status Report 2016".

IETA. 2014. "Allowance Reserves Across Emissions Trading Systems". Available at: http://www.ieta.org/resources/EU/2030-Package/MSR_Market_Stability_Reserve/market%20reserve%20across%20etss_draft_3_clean.pdf (retrieved May 19, 2017).

IPCC, Climate Change. 2014. "Mitigation of Climate Change — Summary for Policy Makers".

Johannsdottir, L. and C. McInerney. 2016. "Calls for Carbon Markets at COP21: A Conference Report". *Journal of Cleaner Production.*

Jotzo, F. 2012. "Australia's Carbon Price". *Nature Climate Change.* 2(7): 475–6.

Kill, J., S. Ozinga, S. Pavett, and R. Wainwright. 2010. "Trading Carbon: How it Works and Why it is Controversial". FERN. Available at: http://www.fern.org/sites/fern.org/files/tradingcarbon_internet_FINAL.pdf.

Klinsky, S. 2013. "Bottom-up Policy Lessons Emerging from the Western Climate Initiative's Development Challenges". *Climate Policy.* 13(2): 143–69.

Knudsen, O. K. 2015. "Towards a Fair and Rigorous International Emissions Trading System: A Blueprint for Success". In: *Achieving Dynamism in an Anaemic Europe.* Springer International Publishing. 275–83.

Koch, N., S. Fuss, G. Grosjean, and O. Edenhofer. 2014. "Causes of the EU ETS Price Drop: Recession, CDM, Renewable Policies or a Bit of Everything? — New Evidence". *Energy Policy.* 73: 676–85.

Kollmuss, A., L. Schneider, and V. Zhezherin. 2015. "Has Joint Implementation Reduced GHG Emissions? Lessons Learned for the Design of Carbon Market Mechanisms (No. 2015–07)". Stockholm Environment Institute Working Paper.

Kopsch, F. 2012. "Aviation and the EU Emissions Trading Scheme — Lessons Learned From Previous Emissions Trading Schemes". *Energy Policy.* 49: 770–3.

Kossoy, A., G. Peszko, K. Oppermann, N. Prytz, N. Klein, K. Blok, and B. Borkent. 2015a. "State and Trends of Carbon Pricing".

Kossoy, A., G. Peszko, K. Oppermann, N. Prytz, A. Gilbert, N. Klein, L. Lam, and L. Wong. 2015b. *Carbon Pricing Watch 2015.* Washington, DC: World Bank. DOI: 10.1596/978-1-4648-0268-3.

Lee, M. 2011. *Fair and Effective Carbon Pricing: Lessons From BC.* Canadian Centre for Policy Alternatives, BC Office.

Lesiuk, T., S. McDonald, D. Peterson, R. Draeseke, and S. Wehr. 2011. "Protocol for the Creation of Forest Carbon Offsets in British Columbia". Government of British Columbia. Available at: http://www.pacificcarbontrust.com/assets/Uploads/Protocols/Forest-Carbon-Offset-Protocol.pdf.

Liu, L., C. Chen, Y. Zhao, and E. Zhao. 2015. "China' s Carbon-emissions Trading: Overview, Challenges and Future". *Renewable and Sustainable Energy Reviews.* 49: 254–66.

Liu, Y. and T. Wei. 2014. "Linking the Emissions Trading Schemes of Europe and China-Combining Climate and Energy Policy Instruments". *Mitigation and Adaptation Strategies for Global Change*: 1–17.

Lucia, J. J., M. Mansanet-Bataller, and Á. Pardo. 2015. "Speculative and Hedging Activities in the European Carbon Market". *Energy Policy.* 82: 342–51.

Olsson, A., S. Gronkvist, M. Lind, and J. Yan. 2016. *Environmental Science & Policy: The Elephant in the Room — A Comparative Study of Uncertainties in Carbon Offsets.* Elsevier. DOI: 10.1016/j.envsci.2015.11.004.

Pacific Carbon Trust. 2014. "Annual Report 2013/2014". Available at: http://www.pacificcarbontrust.com/assets/Uploads/Corporate-Documents/PCT-Annual-Report-Service-Plan-2014.pdf (accessed March 22, 2016).

Pacific Carbon Trust. 2016. "Carbon Neutral Government". Available at: http://www.pacificcarbontrust.com/ (accessed March 22, 2016).

Pang, T. and M. Duan. 2015. "Cap Setting and Allowance Allocation in China's Emissions Trading Pilot Programmes: Special Issues and Innovative Solutions". *Climate Policy*: 1–21.

Pang, T., L. Zhou, and M. Duan. 2015. "Linking China's Emissions Trading Pilot Schemes". *Chinese Journal of Population Resources and Environment.* 13(3): 215–22.

Papageorgiou, A., M. Skordoulis, C. Trichias, D. Georgakellos, and M. Koniordos. 2015. "Emissions Trading Scheme: Evidence from the European Union Countries". In: *Creativity in Intelligent Technologies and Data Science.* Springer International Publishing. 204–15.

Peng, S., Y. Chang, and J. Zhang. 2015. "Consideration of Some Key Issues of Carbon Market Development in China". *Chinese Journal of Population Resources and Environment*. 13(1): 10–15.

Qi, S. Z. and S. Chen. 2015. "Annual Review of Low-Carbon Development in China 2015: Comparative Study in China's Carbon Emissions Trading Pilots". Available at: http://www.brookings.edu/btc (retrieved November 25, 2016).

Qi, S. and B. Wang. 2013. "Fundamental Issues and Solutions in the Design of China's ETS Pilots: Allowance Allocation, Price Mechanism and State-owned Key Enterprises". *Chinese Journal of Population Resources and Environment*. 11(1): 26–32.

Rahman, S. M. and G. A. Kirkman. 2015. "Costs of Certified Emission Reductions Under the Clean Development Mechanism of the Kyoto Protocol". *Energy Economics*. 47: 129–41.

Ranson, M. and R. N. Stavins. 2016. "Linkage of Greenhouse Gas Emissions Trading Systems: Learning From Experience". *Climate Policy*. 16(3): 284–300.

Reinaud, J. 2008. *Climate Policy and Carbon Leakage: Impacts of the European Emissions Trading Scheme on Aluminium*. International Energy Agency, IEA.

Reinaud, J. 2009. "Trade, Competitiveness and Carbon Leakage: Challenges and Opportunities". *Energy, Environment and Development Programme Paper*. 9(01).

Richter, J. L. and L. Mundaca. 2013. "Market Behavior Under the New Zealand ETS". *Carbon Management*. 4(4): 423–38.

Robson, A. 2014. "Australia's Carbon Tax: An Economic Evaluation". *Economic Affairs*. 34(1): 35–45.

Roppongi, H., A. Suwa, and J. A. Puppim De Oliveira. 2016. "Innovating in Sub-National Climate Policy: The Mandatory Emissions Reduction Scheme in Tokyo". *Climate Policy*: 1–17.

Rudolph, S. and T. Kawakatsu. 2012. "Tokyo's Greenhouse Gas Emissions Trading Scheme: A Model for Sustainable Megacity Carbon Markets?" Joint Discussion Paper Series in Economics, No. 25–2012. ISSN 1867–3678. Available at: http://www.uni-marburg.de/fb02/makro/forschung/magkspapers/index_html%28magks%29 (accessed April 4, 2016).

Rudolph, S. and T. Morotomi. 2016. “Acting Local! An Evaluation of the First Compliance Period of Tokyo’s Carbon Market”. *Carbon and Climate Law Review*. 10(1): 75–8.

Smith, S. and J. Swierzbinski. 2007. “Assessing the Performance of the UK Emissions Trading Scheme”. *Environmental and Resource Economics*. 37(1): 131–58. ISSN: 0924-6460. DOI: 10.1007/s10640-007-9108-5.

Sopher, P. and A. Mansell. 2013. “Switzerland: The World’s Carbon Markets: A Case Study Guide to Emissions Trading. Environmental Defense Fund and International Emissions Trading Association”. Available at: http://www.edf.org/sites/default/files/EDF_IETA_Switzerland_Case_Study_May_2013.pdf (accessed June 29, 2016).

Sopher, P. and A. Mansell. 2014. “South Korea: The World’s Carbon Markets: A Case Study Guide to Emissions Trading. Environmental Defense Fund and International Emissions Trading Association”. Available at: http://www.ieta.org/resources/Resources/Case_Studies_Worlds_Carbon_Markets/2014-EDFCaseStudyMarch/south%20korea%20ets%20case%20study%20march%202014.pdf (accessed April 4, 2016).

State of California. 2014. “Memorandum of Understanding To Enhance Cooperation on Climate Change and the Environment between the State of California of the United States of America and the Ministry Of Environment and Natural Resources and the National Forestry Commission of the United Mexican States”. Available at: https://www.gov.ca.gov/docs/7.28_Climate_MOU_Eng.pdf (Accessed April 24, 2017).

Sumner, J., L. Bird, and H. Dobos. 2011. “Carbon Taxes: A Review of Experience and Policy Design Considerations”. *Climate Policy*. 11(2): 922–43.

Swartz, J. 2016. *China’s National Emissions Trading System: Implications for Carbon Markets and Trade; ICTSD Global Platform on Climate Change, Trade and Sustainable Energy; Climate Change Architecture Series: Issue Paper No. 6*. Geneva, Switzerland: International Centre for Trade and Sustainable Development, www.ictsd.org.

Swartz, J. and K. Upston-Hooper. 2013. “Emissions Trading in Kazakhstan: Challenges and Issues of Developing an Emissions Trading Scheme”. *Carbon and Climate Law Review*. (1): 71–3.

Taylor, R. and R. Hoyle. 2014. "Australia Becomes First Developed Nation to Repeal Carbon Tax". *The Wall Street Journal.* 17.

Tokyo Metropolitan Government, Bureau of the Environment. 2010. "Tokyo Cap-and-Trade Program: Japan's First Mandatory Emissions Trading Scheme". Available at: https://www.kankyo.metro.tokyo.jp/en/attachement/Tokyo-cap_and_trade_program-march_2010_TMG.pdf (accessed April 21, 2017).

UNEP. 2014. "The Emissions Gap Report 2014". United Nations Environment Programme (UNEP), Nairobi.

UNFCCC. 2014. "International Emissions Trading". Available at: http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php (accessed April 7, 2016).

UNFCCC. 2015. "INDCs as Communicated by Parties". Available at: http://www4.unfccc.int/Submissions/INDC/Submission%20Pages/submissions.aspx (accessed on May 11, 2016).

UNFCCC. 2016. "What is CDM?" Available at: http://cdm.unfccc.int/about/index.html (accessed April 8, 2016).

United Nations. 1998. "Kyoto Protocol to the United National Framework Convention on Climate Change". Available at: http://unfccc.int/resource/docs/convkp/kpeng.pdf#page=12 (accessed April 8, 2016).

United Nations. 2002. "United Nations Conference on Environment & Development". Available at: https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (accessed April 24, 2017).

Wang, H. 2016. "Evaluating Regional Emissions Trading Pilot Schemes in China's Two Provinces and Five Cities". Asian Growth Research Institute, Working Paper Series Vol. 2016–01.

Wang, W. and S. Wu. 2013. "Research Report on Forest Carbon Sequestration Project Mechanism in North America".

Wara, M. 2014. "California's Energy and Climate Policy: A Full Plate, but Perhaps Not A Model Policy". *Bulletin of the Atomic Scientists.* 70(5): 26–34. DOI: 10.1177/0096340214546832.

Western Climate Initiative. 2013. "Organization". Available at: http://www.westernclimateinitiative.org/organization (retrieved July 16, 2013).

Wittneben, B. B. 2009. "Exxon is Right: Let Us Re-examine Our Choice for A Cap-and-Trade System Over a Carbon Tax". *Energy Policy.* 37(6): 2462–4.

Wood, P. J. and F. Jotzo. 2011. “Price Floors for Emissions Trading”. *Energy Policy*. 39(3): 1746–53.

World Bank, Ecofys and Vivid Economics. 2016. *State and Trends of Carbon Pricing 2016*. Available at: https://openknowledge.worldbank.org/handle/10986/25160 (accessed April 21, 2017) License: CC BY 3.0 IGO. Washington, DC: World Bank.

Xiong, L., B. Shen, S. Qi, L. Price, and B. Ye. 2016. “The Allowance Mechanism of China’s Carbon Trading Pilots: A Comparative Analysis with Schemes in EU and California”. *Applied Energy*.

Zhang, D., V. J. Karplus, C. Cassisa, and X. Zhang. 2014. “Emissions Trading in China: Progress and Prospects”. *Energy Policy*. 75: 9–16.

Zhang, W. and X. J. Wang. 2002. “Modeling for Point-Non-Point Source Effluent Trading: Perspective of Non-Point Sources Regulation in China”. *Science of the Total Environment*. 292(3): 167–76.