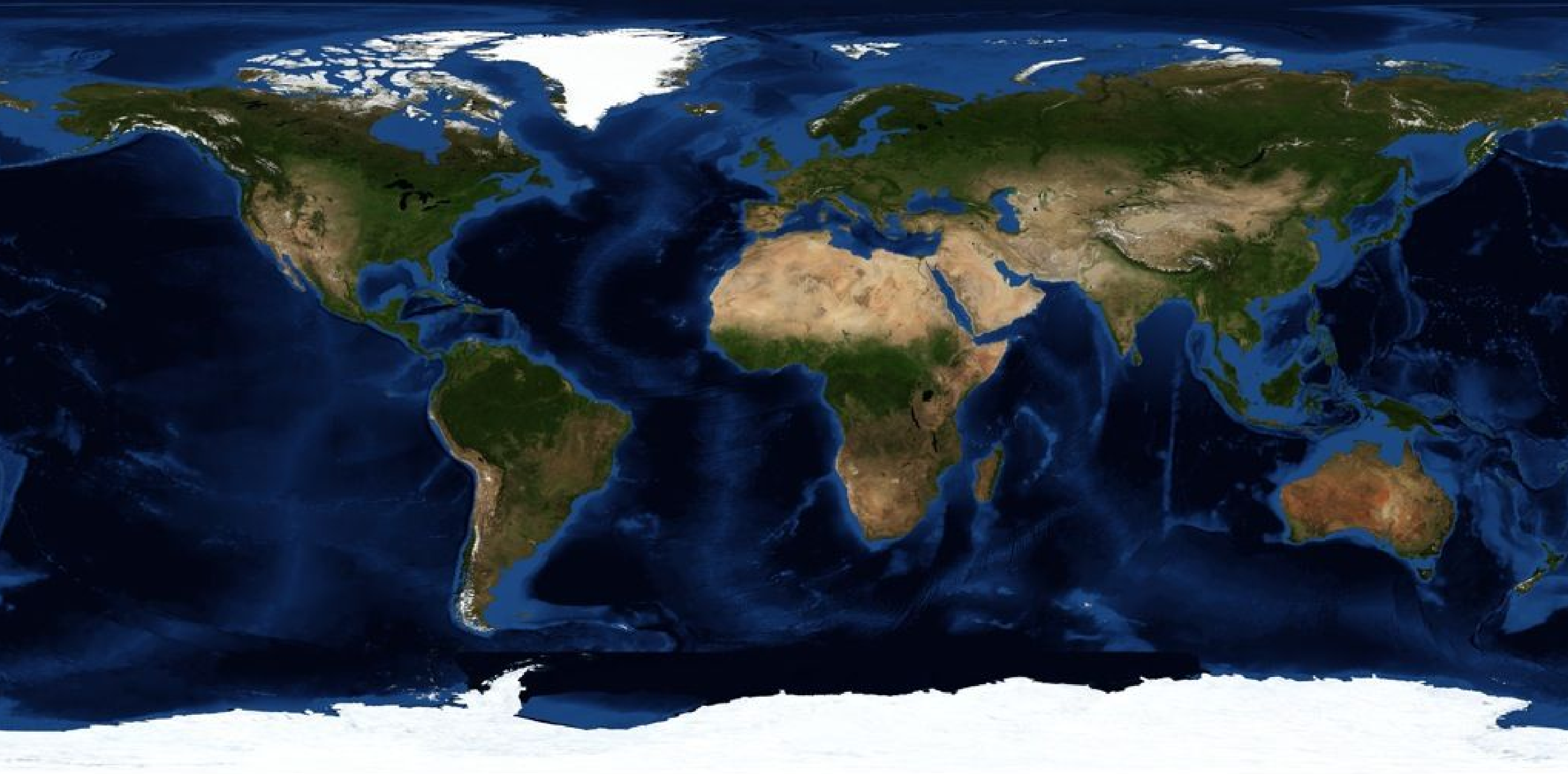

Status and Development Trends of the World's Carbon Market

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EXECUTIVE SUMMARY

Experts agree that the most severe impacts of climate change can be avoided if the global rise in temperature remains below 2^{o} C. However, meeting this goal will require more aggressive and extensive action than the current policies and promises of the Paris Agreement (UNFCCC 2015; Kossoy et al. 2015b). The notion of employing a global emissions trading scheme (ETS) to help meet global reduction targets was first 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. 2015b). An international ETS has continued to be an important point of discussion in climate policy and is acknowledged in the Paris Agreement as a necessary tool for addressing climate change (Johannsdottir & McInerney 2016).

A carbon market refers to any market created through the trading of carbon (or carbon equivalent) allowances, which permit the holder of an allowance to emit the equivalent tonnes of CO_{2e}. 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 (DECC 2015). The most mainstream ETS design is cap-and-trade, which involves setting an absolute cap on emissions above a baseline emissions level and either trading additional emissions or purchasing extra if needed (Kill et al. 2010; Roppongi et al. 2016). Carbon markets have been introduced all over the world at many different levels of enforcement (sub-national, regional, national, and supranational) (Ranson & Stavins 2016), with 40 countries currently operating 18 carbon market systems, all of which exemplify varying characteristics, strategies, linking potential, and levels of success. This paper compares these currently operating carbon markets to determine the benefits and limitations of varying strategies. It reviews all 18 , including their design, rules and regulations, to provide recommendations for the development of an effective, environmentally and economically responsible ETS with linkage potential for eventual creation of an inclusive global carbon market system.

The European Union Emissions Trading Scheme (EU ETS) is the world's largest and longest running cap-and-trade system (European Commission (EC) 2016; Lucia 2015; Ellerman 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 (Kopsch 2012; Ellerman et al. 2015; EC 2013). With such a long history and multiple alterations to its structure, the EU ETS provides a valuable example for other developing carbon markets around the world. This system continues to face many areas of concern, however, primarily the collapse of allowance prices (from EUR$30 per tonne at their peak in 2006 to less than EUR$5 per tonne at the start of 2013) due to a growing surplus of allowances (EC 2016; Ellerman et al. 2015; Kopsche 2012). Causes of this market instability have primarily included over-allocation, grandfathering and banking of allowances (Kill et al. 2010), which are traits that should subsequently be avoided in other carbon market systems.

The Western Climate Initiative (WCI) is the largest, most comprehensive GHG trading system in North America. Two of the five participating jurisdictions have successfully implemented ETSs to date, namely California and Quebec (Houle et al. 2015), with an additional two markets now scheduled for implementation in Ontario and Manitoba (ICAP 2016). The California ETS was launched in 2012 and acts as a primary example of how to incorporate other climate policies within an ETS to help meet reduction goals. This system has benefitted from the beginning by carefully observing the EU ETS and avoiding similar errors in design, such as over-allocation of free allowances (Cullenward 2014). It is clear that emissions in California have decreased, yet there remain mixed opinions on the success of this market (Cullenward 2014; Wara 2014), as California's environmental progress is not necessarily due to the cap-and-trade program, but instead is due to the implementation of a range of other environmental policies and regulatory programs. This system additionally suffers from extreme instances of carbon leakage (Cullenward 2014; Wara 2014), resulting in a weak emissions cap. California's market highlights the importance of regulating leakage, but also the need for a more expansive regional or international market to avoid this issue to begin with.

A smaller scale carbon market in North America is the Regional Greenhouse Gas Initiative (RGGI), which is a cooperative effort among 9 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 (RGGI Inc. 2016; Fell & Maniloff 2015). As with the WCI, the main concern with RGGI is carbon leakage, although the negative environmental impacts of leakage in this system are not as pressing as in California. An important favorable characteristic of this system is that, unlike the EU ETS, RGGI has a price floor for the auctioning of credits, meaning that although permit prices have dropped quite low, the price floor prevents a complete price collapse (Fell & Maniloff 2015). The importance of this feature was demonstrated by the collapse of the Chicago Climate Exchange (CCX) in 2010, which should prompt implementation of a similar feature in systems threatened with low carbon prices, such as the EU, China and New Zealand.

As the largest GHG emitter in the world, development of a national ETS in China is crucial for the success of global efforts to mitigate climate change. Prior to implementing a national ETS, seven pilot ETSs were formed in two provinces (Guangdong and Hubei) and five cities (Beijing, Shanghai, Tianjin, Shenzhen and Chongqing) in October 2011 (Liu et al. 2015; Wang 2016). Based on the most successful components of these seven pilot systems, a national ETS is scheduled for implementation in 2017. This system will have 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). The Chinese pilot systems have many concerning features, including over-allocation, weak trading rules and poor MRV (monitoring, reporting and verification), with these pilots ultimately prioritizing economic development (Zhang et al. 2014). Other concerning features include the use of an intensity target as opposed to an absolute cap, ex-post adjustment of emission allowances, free allocation of permits and over-allocation of permits (Liu & Wei 2014; Pang & Duan 2015; Duan et al. 2014). 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 important responsibility in the international community to make wise decisions regarding carbon market development and linkage. As such, a top-down, centrally controlled national market is recommended, as opposed to an attempted linkage of the seven existing pilot markets. In order to ensure environmental benefits are not disregarded in preference for economic benefits, components of the current Chinese system that favour economic development at the expense of environmental benefits should be addressed. Other recommendations for this system include a unified national platform for trading, centrally developed legislation and a related independent regulatory department (Liu et al. 2015), a strong compliance and enforcement plan (Swartz 2016) and improved rules and regulations to ensure timeliness and transparency of information (Xiong et al. 2016).

Other current cap-and-trade systems in Asia and Oceania include New Zealand, Japan, Kazakhstan and South Korea. New Zealand's ETS is unique in that it is run in a bottom-up design with no fixed cap in order to include the forestry sector and accommodate carbon sequestration from forestry activities. This system was originally designed to allow for unlimited use of international offset credits, but due to the oversupply of cheap international emissions credits, the country no longer allows KP-related credits to be traded within its ETS (Kossoy et al. 2015b). Japan has two city-sized ETSs in Tokyo and Saitama, which are nearly identical in design. These systems benefit from many unique characteristics including strong leadership and administrative capacity, stakeholder involvement in policy formulation and implementation, availability of data to support policy decisions, gradual implementation of compliance, no free allocation of tradeable credits, transparent monitoring, and a focus on energy consumers rather than entities within specific sectors (Rudolph & Kawakatsu 2012; Roppongi et al. 2016). These systems demonstrate the effectiveness of having a compulsory monitored cap that is strictly regulated (Roppongi et al. 2016) and have led to significant reductions in CO_2 emissions, albeit on a small scale (Rudolph & Kawakatsu 2012; Roppongi et al. 2016). Kazakhstan, on the other hand, has taken a larger scale approach, implementing a mandatory nationwide ETS in 2013. The future of this system is uncertain, however, with a new incoming government in 2016 suspending the system for two years (until 2018) due to industry protests (Climate Policy Observer 2016). South Korea has also recently implemented a nationwide ETS in January 2015. Unique features of this system include the use of additional allowance credits as rewards for early reduction and the use of ex-post adjustment as a price control measure. This system is young and its effectiveness, public and industry acceptance, and potential for international linkage will become clearer over time.

There are many incentives for the development of an international carbon market, as it would allow for increased economic efficiency of emissions reductions, more stability in prices and consistency between markets, greater flexibility and liquidity in meeting reduction targets, less market power for large participants, lower transaction costs and less risk of carbon leakage (Johannsdottir & McInerney 2016; Kossoy et al. 2015b; Ranson & Stavins 2016; Carbone et al. 2009; Haites 2016; Kill et al. 2010; Hawkins & Jegou 2014). As a result, many argue that existing trading systems should become compatible and linkable, with similar methodology, tools, standards and indicators (Johannsdottir & McInerney 2016; Ranson & Stavins 2016; Carbone et al. 2009; Haites 2016; Kill et al. 2010). Current attempts at international carbon market development are results of the KP, including the Clean Development Mechanism (CDM) and Joint Implementation (JI) (UNFCCC 2014). These mechanisms function by coordinating offset projects that supply offset credits to pre-existing carbon markets around the world, thereby linking those markets indirectly. Although these mechanisms provide flexibility for countries to meet their targets, and in the case of CDM, can act to stimulate sustainable development (Rahman & Kirkman 2015; UNFCCC 2016a), the regulation of these systems has faced much criticism as research has shown that they have led to an increase in GHG emissions above KP targets (Kollmuss et al. 2015). This is a threat to the environmental integrity of ETSs in countries that plan to link internationally, as the incorporation of these credits into the EU ETS, for example, is estimated to be undermining the EU's reduction target by about 400 million tCO_{2e} (Kollmuss et al. 2015). While a new market mechanism has been proposed by the Paris Agreement as a more holistic approach to an international carbon market (Gavard et al. 2013), development of this mechanism should consider the many lessons that have been learned from previous global market attempts under the KP: 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 favoritism of non-additional projects (Kollmuss et al. 2015).

CDM and JI represent one strategy for constructing a global carbon market using the indirect linkage of national and regional ETSs through the common use of credits. There are three other possible scenarios for global carbon market development, including a top-down global trading system based on an international treaty, formal linking of domestic ETSs to construct an international market bottom-up, or a mixture between these approaches, containing elements from each (Flachsland et al. 2008; Rudolph & Kawakatsu 2012). Three crucial elements that must be considered when developing an international carbon market framework are: the ability to link carbon market systems together between countries and regions; transparent and consistent rules that account for the transfer of international emissions reductions; and tools and regulations that allow for links between different carbon-pricing systems (Johannsdottir & McInerney 2016). The current state of carbon markets and recently proposed INDCs (Independent Nationally Determined Contributions) suggest emergence of a decentralized bottom-up market design, as opposed to the indirect, top-down linkage previously attempted by the KP. As top-down global climate negotiations have progressed slowly, the emerging bottom-up mitigation efforts may be a more practical option to coordinate climate action (Liu & Wei 2014). Under this structure, carbon markets could be a promising way to facilitate cooperation and achieve the 2°C goal set by the Paris Agreement, as long as it is regulated transparently, stringently, and with positive environmental intentions and integrity (Kossoy et al. 2015b).

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ABBREVIATIONS

AAU	Assigned Amount Units
ACCU	Australian Carbon Credits Units
ARB	Air Resources Board
BAU	Business as Usual
CCER	Chinese Certified Emissions Reduction
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CER	Certified Emissions Reduction
CFI	Carbon Financial Instrument
COP21	21st UNFCCC Conference of the Parties
DAP	Direct Action Plan
EC	European Commission
ERF	Emissions Reduction Fund
ERU	Emissions Reduction Unit
ETS	Emissions Trading Scheme/System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IET	International Emissions Trading
INDC	Independent Nationally Determined Contributions
JI	Joint Implementation
KP	Kyoto Protocol
LULULF	Land Use, Land-Use Change and Forestry
MRV	Monitoring, Reporting and Verification
NDRC	National Development and Reform Commission
NMM	New Market Mechanism
PAT	Perform, Achieve and Trade
PCT	Pacific Carbon Trust
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RGGI	Regional Greenhouse Gas Initiative
RMU	Removal Unit
UNFCCC	United Nations Framework Convention on Climate Change
WCI	Western Climate Initiative

GLOSSARY

Benchmarking: An allowance allocation method in which allowances are distributed based on a specified benchmark (level) of emissions.

Bottom-up: Creation of a decentralized, larger scale carbon market through coordination of smaller scale, independent national or regional systems.

Cap: The upper limit of GHG emissions that can be emitted within a given time period, or the total number of emissions allowances that are available to covered entities within a cap-and-trade ETS. An **absolute cap** is a fixed number of emissions that ensures emissions do not exceed a given, known limit. An **intensity cap** is a limit of GHG emissions that depends on GDP, allowing flexibility for changes in the cap with economic growth.

Cap-and-trade: The most mainstream design of an emissions trading system, which involves setting a cap on emissions above a baseline emission level and either trading additional emissions if reaching below the cap, or purchasing extra if surpassing the cap.

Carbon leakage: A phenomenon that occurs when companies move their production or investments to another jurisdiction where the cost of emissions are lower. Aggregate emissions can actually increase if emissions move to more emission intensive areas, undermining any positive environmental intentions of the carbon market.

Carbon market: Any market created through the trading of carbon (or carbon equivalent) allowances (or permits), which allow the holder of a permit to emit the equivalent tonnes of CO_{2e}.

Carbon offset: A unit of CO_{2e} that is reduced, sequestered or avoided 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.), which can be used to cancel out their own emissions and help meet their reduction target.

Carbon pricing: Any system that puts a price on GHG emissions. There are two main methods of pricing carbon: a carbon market and a carbon tax.

Carbon tax: A tax on CO_2 emissions from burning fossil fuels. By putting a price on each tonne of GHG emitted, a carbon tax leads to a gradual market response by creating an incentive for emitters to shift to less emissions intensive production.

Clean Development Mechanism: A mechanism created by the Kyoto Protocol that regulates offset projects in countries that do not have emissions reduction targets (Non-Annex I) to help Annex I countries meet their reduction targets. A CDM project generates certified emission reduction (CER) credits.

Compliance period: A set amount of time given to each participating entity in an emissions trading scheme to reach their emissions reduction goal, and at the end of which each entity must surrender enough allowances to cover its GHG emissions during that period.

Coverage threshold: A set size or emissions intensity that determines whether a facility must participate in the emissions trading system. Mandatory capped entities are companies that exceed a certain size or annually emit a certain volume of GHG emissions, with the threshold varying between systems.

Emission allowance: A government-issued authorization to emit a certain amount of GHGs. An allowance is commonly denominated as 1 tCO_{2e} per year, with the total number of allowances distributed to participating entities determining the overall emissions cap of the system. Also referred to as a **carbon allowance** or an **emissions/carbon permit**.

Emissions trading system: A market-based approach for controlling GHG emissions by providing an economic incentive to reduce emissions through the buying and selling of emission allowances/permits. The most common design of an emissions trading system is a cap-and-trade system.

Forest carbon: Carbon stored in forest ecosystems in both dead and living organic matter above and below ground (including trees, understory, dead wood, litter and soil).

Grandfathering: An allowance allocation method in which allowances are distributed based on historical emissions or expected future requirements.

Greenhouse gas: Any gas that contributes to the greenhouse effect by absorbing infrared radiation in the atmosphere. The IPCC identifies six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6)

Joint Implementation: A mechanism created by the Kyoto Protocol that regulates offset projects within capped (Annex I) countries. A JI project generates emission reduction units (ERUs) that can be used towards meeting reduction targets

Kyoto Protocol: An international treaty within the framework of the UNFCCC that entered into force in 2005 and commits parties to reduce GHG emissions. The Kyoto Protocol introduced three market-based mechanisms for GHG emissions reductions: International Emissions Trading, Clean Development Mechanism and Joint Implementation.

Linkage: Coordination of allowance credits between multiple emissions trading systems. Linkage can be indirect (through common use of an external credit, such as CDM and JI) or direct (through trade of allowances directly between systems). Direct trade can be characterized by either unilateral, bilateral, or multilateral linkage. Under a **unilateral link**, entities in one system can purchase and use allowances from another system for compliance, but not vice versa. In a **bilateral link**, allowances can be freely traded between two systems with each system's allowances being equally valid for compliance in both systems. If more than two schemes participate, this becomes a **multilateral link.**

Paris Agreement: An international treaty within the framework of the UNFCCC to be entered into force in 2020. This treaty was the outcome of COP21 in December 2015 and includes INDCs from 175 participating countries that cover GHG emissions mitigation, adaptation and finance goals.

Price floor: A regulatory policy that determines the minimum value participating entities in an emissions trading system must pay for an emissions allowance. A common method for introducing a price floor into an emissions trading system is the use of an allowance reserve.

Top-down: Creation of a centralized, large-scale carbon market through formal engagement between sovereign states, often leading to adoption of a universal treaty.

Trading period: A set amount of time in which reduction goals must be met by participating entities in an emissions trading system to avoid paying a fine, either by reducing emissions, purchasing additional allowance credits, or purchasing offset credits

1. INTRODUCTION

Due to the global nature of climate change, international cooperation is a requirement of any solution that will effectively address this issue. Experts agree that the most severe impacts of climate change can be avoided if the global rise in temperature remains below 2°C (Kossoy et al. 2015b). This goal was recently set as a fundamental outcome of the Paris Agreement in December 2015, but will require more aggressive and largescale action than the current policies and Intended Nationally Determined Contributions (INDCs) of this agreement (UNFCCC 2015; Kossoy et al. 2015b). An estimated emissions reduction of 40-70% from 2010 levels by 2050 is required in order to make this goal possible (UNEP 2014; IPCC 2014). The majority of current financial resources associated with climate change (a total of about USD$350 billion annually) is spent on mitigation efforts, but in order to meet this reduction and stabilize the climate, this value must dramatically increase and investment patterns must shift more towards long-term, low-carbon solutions.

This disjunction between ambitious targets and less than ambitious policies and practices is not new, and has prompted the notion of a global emissions trading scheme (ETS), first popularized by the Kyoto Protocol (KP) in 2005, as a strategy for international action to help meet such targets (Roppongi et al. 2016; UN 1998). Since then, the share of emissions covered by carbon pricing has tripled and, by August 2015, approximately 39 national jurisdictions and 23 cities, states and regions had implemented a price on carbon, covering about 7 $GtCO_{2e}$ (12% of global emissions) (Kossoy et al. 2015b). An international ETS has continued to be a pivotal point of discussion in climate policy and has been acknowledged in the recent Paris Agreement as a necessary tool for addressing climate change (Johannsdottir & McInerney 2016).

A carbon market refers to any market created through the trading of carbon (or carbon equivalent) allowances (or permits), which allow the holder of a permit to emit the equivalent tonnes of $CO_{2e.}$ As such, the terms carbon market and ETS are used interchangeably throughout this report. Carbon trading is the process of buying and selling these permits when, if the holder's emissions are lower than this quota, they can sell the surplus, or conversely, if emissions exceed the quota, a holder can buy additional permits on the market (Kill et al. 2010). 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 greenhouse gas (GHG) emissions (DECC 2015). The most mainstream ETS design is cap-and-trade, which involves setting an absolute cap on emissions above a baseline level and either trading additional emissions if emitting below the cap, or purchasing extra if surpassing the cap (Kill et al. 2010; Roppongi et al. 2016). 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 (Helm 2003; Cullenward 2014).

Carbon markets have been introduced all over the world at many different levels of enforcement: sub-national implementation, such as in California and Tokyo; regional implementation, such as the

Regional Greenhouse Gas Initiative (RGGI); national-level implementation, such as in New Zealand and Switzerland; and supranational implementation, such as the European ETS (EU ETS) (Ranson & Stavins 2016). There are currently 40 countries in the world operating 18 carbon market systems, in addition to the international emissions trading mechanisms under the KP, all of which exemplify varying characteristics, strategies, linking potential, and levels of success. There are five main factors to consider for successful implementation of an ETS: setting a cap that produces reasonable prices and emissions reductions; allocating permits in an equitable way with a balance between grandfathering (allowances distributed for free) and auctions (charging emitters a price for each allowance) that creates support for the system; trading regulations that allow flexibility but avoid carbon leakage; monitoring of emissions reliably and continuously with high integrity; and finally, strong compliance achieved by ensuring a stable system that allows industry to reliably meet their environmental goals (Central Pollution Control Board (CPCB) 2013; Kopsch 2012; Cullenward 2014; Johannsdottir & McInerney 2016).

China and the USA are currently the two countries with the largest volume of emissions covered by carbon pricing instruments, and the EU ETS is the single largest international carbon pricing system (Kossoy et al. 2015b). The combination of all carbon pricing mechanisms is estimated to have a value of USD$50 billion globally in 2015, with 70% attributed to ETSs and 30% to carbon taxes (Kossoy et al. 2015b). Although many of these jurisdictions have expressed interest in linking their domestic cap-and-trade policies, developing an effective international carbon market design has proven to be very challenging thus far (Ranson & Stavins 2015). The goal of this paper is to review how these factors are addressed in the currently operating carbon markets around the world to determine the benefits and limitations of varying strategies. It reviews all 18 markets, including their design, rules and regulations, to provide recommendations for development of an effective, environmentally and economically responsible ETS with linkage potential to create an effective global carbon market system.

Benefits and Limitations of Carbon Markets

Carbon markets are an attractive strategy to limit GHG emissions as they are, in principle, a cost-effective method of mitigating emissions while encouraging innovation, investment in low-carbon technologies, and efficient use of fossil fuels (Kossoy et al. 2015b). These markets are an important strategy to incentivize investment in low carbon technologies, as current annual investment in green infrastructure is USD$360 billion, but will be required to reach approximately USD$5.7 trillion by 2020 if the 2^{o}C target is to be realized (Johannsdottir & McInerney 2016). Carbon markets are especially important as they are the mechanism that has been most widely adopted to date as a strategy for addressing climate change (Kossoy et al. 2015b; Knudson 2015). Some even suggest that, if the international approach to climate change is to be fair and rigorous by taking into account a country's historic emissions as well as their ability to pay, carbon markets are a necessary condition for reaching the 2^{o}C target (Knudsen 2015). Taking such fairness into account, one researcher suggests that both Europe and the United States would currently be required to set a negative emissions target, further emphasizing the absolutely integral role of international emissions trading in any international climate policy (Knudson 2015). Although carbon markets do have the potential to incentivize technological development and investment in renewable energy, this potential can only be realized if the price of carbon is high enough – considerably higher than its current value (Kill et al. 2010). The majority of 2015 emissions were priced at less than USD$10 per tCO_2e (Kossoy et al. 2015b), while an estimated global average carbon price between USD$80-100 per tCO_{2e} in 2030 is consistent with achieving the 2°C goal (Clarke et al. 2014). Due to their prevalence in current climate policy, carbon markets have undergone much analysis and criticism, including concerns with regards to both the overall design of current markets, as well as the detailed rules and regulations of these systems.

Three main arguments exist against the current structure of carbon markets as an instrument to stabilize climate change: it does not result in the lowest cost to society; it does not promote long-term transitioning to low carbon economies; and it does not work in the interest of the climate. With regards to societal costs, it has been argued that by enabling polluters to meet reduction targets through purchasing of emissions without structural changes, only the short-term costs for companies are lower, while the long-term cost of climate action for the economy and society is increased (Kill et al. 2010; Helm 2003). In some cases, carbon markets can allow industries to delay investment in clean technologies by purchasing carbon permits and offsets, therefore delaying their transition to low-carbon economy infrastructure and creating the opposite effect intended. This mechanism can also work against the interest of the climate when polluters purchase large amounts of permits when CO_2 prices are low and then use them later to continue polluting when prices are high (Kill et al. 2010).

In terms of the detailed regulation and implementation of these systems, there are three main concerns to consider: the link between carbon markets in the developed world and offsetting opportunities in the developing world, which can lead to carbon leakage; lack of regulation and transparency leading to underreported emissions, over-reported offsets or creation of income for certain stakeholders; and an unintentional increase in unsustainable practices, such as the burning of biofuel to sell carbon credits leading to replacement of the previous use of biological residues with a less sustainable substitute (Kossoy et al. 2015b; Haites 2016). Carbon leakage is a key threat to the environmental integrity of all ETSs, as carbon pricing is not currently implemented uniformly around the world. Leakage occurs when companies move their production or investments to another jurisdiction where the cost of emissions are lower (Kossoy et al. 2015b). Effective implementation of an ETS also requires rigorous monitoring of emissions and verification of reported reductions. This requires accurate monitoring and measurement equipment and is currently questionable with many cases of unclear monitoring, reporting and verification (MRV) (Kill et al. 2010). The combination of these factors can lead to an overall increase in emissions, as opposed to the emissions reductions intended by these systems (Kill et al. 2010), and it is therefore very important for these concerns to be fully considered and addressed in future carbon market development.

Role of Carbon Tax in Climate Policy

It is clear that carbon pricing will play a role in the future of climate change policy, in which two dominant methodologies exist: carbon markets and carbon taxes. A carbon tax is effectively a tax on CO_2 emissions from burning fossil fuels. By putting a price on each tonne of GHG emitted, a carbon tax leads to a gradual market response by creating an incentive for emitters to shift to less emissions intensive production, with the ultimate goal of reducing emissions (Kossoy et al. 2015a). This method of carbon pricing first emerged in 1990, with Finland being the first nation to adopt a carbon tax (Sumner et al. 2011). Since then, 15 countries have implemented or passed legislation for a carbon tax (Kossoy et al. 2015a). Existing carbon taxes vary in price with the following values in USD/tCO_2 as of April 1, 2015: Sweden (\$130), Finland (\$62 for transport fuels, \$47 for other fossil fuels), Switzerland (\$62), Norway (\$3-53), Denmark (\$24), British Columbia (\$24), Ireland (\$22), Slovenia (\$19), France (\$15), Iceland (\$8), Portugal (\$5), Latvia (\$4), Mexico (<\$1-3), Estonia (\$2), Japan (\$2), and Poland (<\$1) (Kossoy et al. 2015a).

British Columbia (BC) is an example of successfully taxed carbon, in which a carbon tax applies to all purchase or use of fuels, covering approximately 75% of all GHGs in the province (Pembina Institute 2014; Murray & Rivers 2015). This tax was implemented at CAD\$10/tonne in 2008, and rose by \$5 per tonne per year until reaching \$30/tonne in 2012. As such, current prices in cents/litre are as follows: gasoline (6.67), diesel (7.67), jet fuel (7.83), natural gas (5.70 cents/cubic meter), propane (4.62), and coal (53.31 low heat, 62.31 high heat) (Pembina Institute 2014). A unique aspect of this system is that the BC Carbon Tax Act requires that any money raised through carbon tax must be used to reduce other provincial taxes, making this a revenue neutral system (Pembina Institute 2014). As such, money raised by the carbon tax goes towards reducing personal income tax and various business taxes, but still leads to a reduction in GHG emissions by making it cheaper for consumers to act sustainably (Ministry of Finance 2012). Estimates suggest that the tax has reduced emissions in the province by 5-15% since implementation, and public opinion, which originally opposed the tax, has shifted to be supportive (Murray & Rivers 2015).

The primary difference between the two carbon pricing mechanisms is that tax puts a price directly on carbon to reduce emissions, while an ETS sets a limit on the quantity of emissions allowed, thus placing a price on carbon (Sumner et al. 2011). The most significant difference between these two approaches is that, in the case of carbon tax, the price of carbon is set by a government body and is therefore more certain and stable, while the price in an ETS can vary with the quantity of emissions allowances and economic cycles (Kossoy et al. 2015a; Wittneben 2009). These pricing approaches also differ in terms of the flow of revenue to the public, cost to the public, marginal cost of reduction, the use of generated money, and duration and commitment (Kossoy et al. 2015a; Wittneben 2009).

The flow of revenue is more stable and certain with a carbon tax, as is the cost of the system to the public, while the price of carbon in an ETS is subject to market fluctuations. Carbon tax rewards reductions at an equal rate no matter how much the reduction costs, whereas ETSs are suspected to provide a higher reward for easier, early reductions, and a lesser reward as the market becomes saturated over time, leading to a lack of incentive for long-term structural change (Wittneben 2009).

The money grossed from a carbon tax is also more easily marked for use by the government for green projects, while spending of ETS revenue by companies is less certain. Finally, a carbon tax is more easily administered for a short period of time as it is fairly easy to implement and conclude, while a carbon market cannot end as easily, as it often involves international connections, invested external interest and a large amount of effort to build the system (Wittneben 2009).

Some suggest that an internationally coordinated carbon tax may be a quicker, simpler and cheaper solution to reducing emissions, with no upper bound on reduction potential (Wittneben 2009). Carbon markets, however, provide the benefit of allowing emissions reductions to take place where the abatement costs are lowest, adjusts automatically for inflation and external price changes, is better equipped to deal with all six GHGs, is more conducive to international agreements with the ability to fix a certain environmental outcome through a reduction target, and lastly, is more appealing to private industry with the flexibility and chance to profit from unused emissions credits.

Given the choice between these two forms of carbon pricing, the best approach is dependent upon the circumstances and context of the jurisdiction, as well as the broader national economic priorities (Kossoy et al. 2015a). Although carbon tax has been discussed as an alternative to cap-and-trade in the past, existing carbon taxes are often combined with other carbon policies and can complement ETSs well (Sumner et al. 2011). ETSs may be more difficult to implement in sectors without point sources (e.g. transportation), and as such, carbon taxes can be used in conjunction with ETSs and other carbon policies. For example, carbon tax in France and Portugal are applicable to specific sectors not included in the EU ETS (Kossoy et al. 2015a; Sumner et al. 2011). Norway's carbon tax covers 68% of CO_2 emissions, while the EU ETS covers 35-40% of its GHG emissions, and Sweden imposes carbon taxes 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 carbon tax with an ETS is increasingly implemented, with features of both instruments combined to form a hybrid approach (Kossoy et al. 2015a; Sumner et al. 2011). Carbon tax is unlikely to replace ETSs as an international policy, as international carbon market development is already in progress, while carbon tax has strictly national or sub-national implementation to date (Kossoy et al. 2015a). A complementary use of both policies may be the most effective means to successfully price carbon.

Paris Agreement

As a result of the 21st Conference of the Parties (COP21), the Paris Agreement has been signed by 175 countries, although most INDCs are yet to be ratified and currently stand as vague goals submitted by each participating country (UNFCCC 2015). Current INDCs require increased ambition in their targets in order for the main goal of the agreement, to minimize temperature rise to 2^{o}C above prehistoric levels, to possibly be met (Kossoy et al. 2015b). Several countries include carbon pricing as an important part of their INDC mitigation strategy and it is these documents that will inform future action on carbon pricing (Kossoy et al. 2015b).

China, Norway and Iceland have stated that ETSs will play a key role in their emissions reduction strategies, and the Republic of Korea, New Zealand, Kazakhstan, Ukraine and Switzerland have highlighted their intention to use international carbon credits to meet their targets (UNFCCC 2015). Other countries, however, such as Andorra, the EU, Gabon, the Marshall Islands, and the United States, have ruled out the use of international credits in their INDCs (Kossoy et al. 2015b). This is a particularly significant statement from both the EU and US, as they are top GHG emitters that play influential roles in international climate policy and carbon trading. The use of forestry and other land-use sectors as an important component of future climate policy is also present in many INDCs, with Canada, Switzerland, New Zealand, Australia, Ukraine and Japan stating that LULUCF will be accounted for in national emissions reduction targets, and with India, China and Kazakhstan highlighting forests as a way to increase carbon sequestration (UNFCCC 2015).

Another noteworthy outcome of the Paris Agreement is the creation of two international market frameworks that allow for international carbon trading (UNFCCC 2015). Article 6 describes the creation of a framework for cooperative approaches to allow for linkage of current ETSs, as well as 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, with the agreement stating that key elements of these mechanisms, such as establishing rules, modalities, procedures and transparent regulation, will be defined in the future (UNFCCC 2015). The NMM is proposed as a holistic market approach that will complement the Clean Development Mechanism (CDM) and Joint Implementation (JI) (UNFCCC 2015) but involve non-Annex I countries beyond their current involvement in the 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.

2. STATUS AND DEVELOPMENT TRENDS

In order to facilitate a meaningful and comparative analysis, this review classifies ETSs by their structural approach, with main groupings including hybrid, top-down, and bottom-up markets. Carbon markets of all scales are addressed, with comparison groups further classified by several important characteristics, including emissions coverage, method of allowance allocation, and whether the system recognizes international carbon offsets (Figure 1). Structural approach refers to the cap-setting methodology of the system, with some systems setting a cap first and allocating allowances downwards, others allocating allowances and then aggregating upwards to form the cap, and others using a mixture of these two approaches at different jurisdictional scales. Emissions coverage is defined to be high or low based on the total amount of emissions included in the scheme, considering both the proportion of total emissions covered as well as the total number of GHGs incorporated in the system. Should the coverage of emissions in the market exceed 50% of total emissions and encompass approximately 3 GHGs or more, the market was subsequently categorized as having high emissions coverage. Similarly, should a carbon market cover less than 50% of absolute emissions and account for fewer than 3 GHGs, the system was categorized as low coverage. Methods employed in the allocation of allowances allowed for another level of comparison amongst markets, in which authorities can distribute emissions allowances freely, through auction, or sell allowances at market price. To facilitate comparable groupings of national and regional carbon markets, allowance allocation was defined to be either mixed in allocation methods, freely allocated, or auctioned depending on the primary method(s) of emissions allowance allocation. Lastly, carbon markets were compared on the basis of recognition of international offsets within the system. Collectively, these critical characteristics of carbon markets facilitated discussion and comparison between systems globally. For further details regarding all currently operating carbon markets, please see Appendix A.

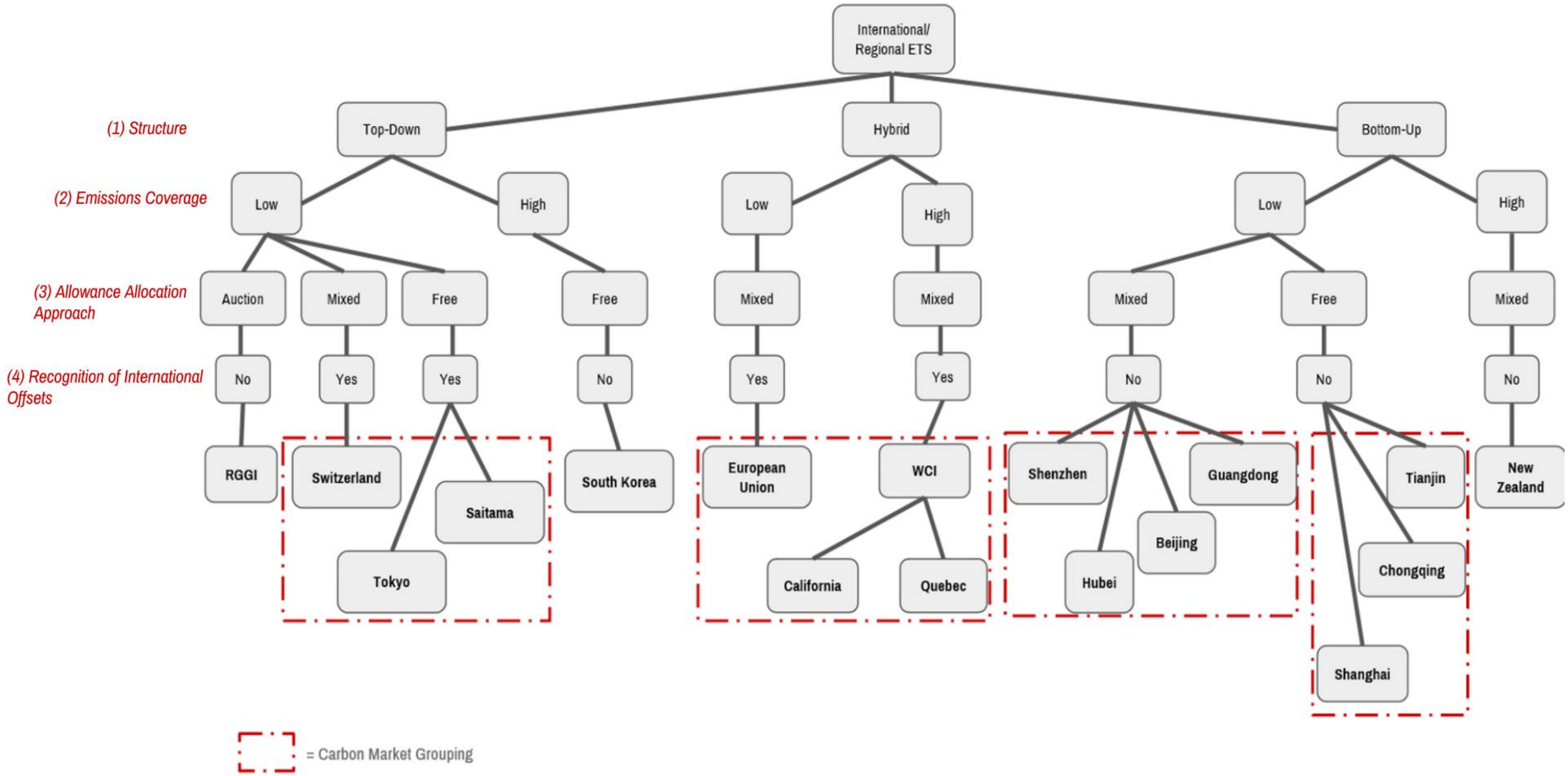

Figure 1. Carbon market groupings are based on the following 4 characteristics: (1) structure, (2) emissions coverage, (3) allowance allocation methodology, and (4) recognition of international offsets.

Hybrid Carbon Markets

European Union Emissions Trading Scheme

The European Union Emissions Trading Scheme (EU ETS) was launched in 2005 as the world's first, largest and longest running cap-and-trade system (European Commission (EC) 2016; Lucia 2015; Ellerman 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, (including its 28 member states and 3 closely associated members, Norway, Iceland and Liechtenstein) (EC 2016; Ellerman et al. 2015) covering approximately 45% of the EU's total emissions (Kopsch 2012; Ellerman et al. 2015; EC 2013). This ETS includes 3 compliance periods (2005-2007, 2008-2012, 2013-2020) with a relatively ambitious end goal of reducing emissions by 21% below 2005 levels by 2020 and by 43% below 2005 levels by 2030 in the sectors covered by the ETS (DECC 2015; Haites 2016; Kossoy et al. 2015b; Kopsch 2012; Kill et al. 2010). These sectors include power stations and combustion installations (greater than 20MW), industry, aviation (added in 2012), CCS installations, and production of petrochemicals, ammonia, non-ferrous and ferrous metals, gypsum, aluminum, nitric, adipic and glyoxylic acid (International Carbon Action Partnership (ICAP) 2016). The scheme currently includes approximately 11,000 stationary installations which emit around 2 billion tonnes of CO_2 (Federal Office for the Environment 2016). The LULUCF sector is not currently under any reduction targets, but Member States are working to improve accounting systems, after which the inclusion of agriculture and forestry sectors will be considered.

The EU ETS operates as a traditional cap-and-trade system where a fixed number of allowances are issued each year (with one allowance permitting the owner to emit 1 tCO_{2e}), and companies are granted flexibility in that they can pay a fine for exceeding their emission allowances, can sell extra allowances or transfer allowances over to the next year, or buy additional allowances from another company (EC 2016; DECC 2015). This cap is then reduced gradually each year by reducing the number of available allowances by 1.74% (DECC 2015; Ellerman 2015). In order to ensure compliance, each member must submit an annual report on its emissions that is investigated by an authorized verifier. The centralized regulatory body of the EU ETS ensures that the cap is complied with and no entities are underreporting their emissions or over reporting offsets (Kill et al. 2016). The European Energy Exchange (EEX) is the leading energy exchange in Europe and the leading auction platform for emissions allowances in the EU ETS, holding regular auctions on its market (EEX AG 2016).

The goal of the EU ETS is to create an incentive for the largest GHG emitters to decrease emissions, and is said to have triggered innovative cross-sectoral collaborations and accelerated investments in renewable energy and coal plant retrofits (EC 2016). Over its 3 phases, the EU ETS has been altered to address various concerns, such as incorporating aviation in phase 2 (although it is still criticized for excluding agriculture and transport) (Kopsch 2012; Haites 2016), extending the trading period in phase 2 to allow for more predictability and encourage longer-term investment (Papageorgiou et al. 2015), and switching from a decentralized structure with each participating country following a

National Allocation Plan, which proved to be inefficient and ineffective in phase I, to a centralized allocation and system-wide cap in phase II (Ellerman et al. 2015; Kill et al. 2010).

As with virtually all operating carbon markets, there continues to be a few areas of concern with this ETS, primarily the collapse of allowance prices reducing the incentive for innovation and green investment. There is a growing surplus of allowances in this market, caused by a number of contributing factors including market design and the 2008 economic crisis, threatening the overall stability of the system (EC 2016; Ellerman et al. 2015; Kopsche 2012). There was a surplus of 83 million allowances at the end of phase I and 1.8 billion at the end of phase II, which according to the design of this ETS, can be banked for use in phase III and later. This has led to a decrease in allowance prices from EUR$30 per tonne at their peak in 2006 to less than EUR$5 per tonne at the start of phase III. The collapse of allowance prices has led to criticism of the system and its success, as a low cost of allowances means they are a negligible incentive for industries to reduce emissions and invest in low-carbon technologies (Ellerman et al. 2015).

The main reasons for this instability include over-allocation, grandfathering and banking of allowances (Kill et al. 2010). Too many allowances were allocated at the beginning of phase I, and the allocation methodology was primarily grandfathering, limiting allowance value. The banking of allowances, in combination with the economic downturn in 2008, allowed the low value of allowances to continue into phases II and III (Kopsch 2012; Kill et al. 2010). Actions are being taken to address this instability in the market by decreasing the cap by 2.21% per year beginning in 2021 (EC 2016), by phasing out grandfathering of emissions credits completely by 2027 (Ellerman et al. 2015), by adopting a Market Stability Reserve to control allowance availability after 2020 (Ellerman et al. 2015), and by requiring that emissions reductions be achieved through domestic action alone with a ban on international offsets starting in 2020 (Hawkins & Jegou 2014).

Offsets currently provide a link between the EU ETS and the Clean Development Mechanism (CDM) and Joint Implementation (JI) (Haites 2016), with the use of certified KP offsets allowed up until 2020 (Ellerman et al. 2015). Offsets (excluding LULUCF projects) can be used to account for up to 50% of reductions (from 2008-2020) – equivalent to approximately 1.6 billion units, of which 540 million remain for use in phase III (Kill et al. 2010; Haites 2016; Ruddell et al. 2006). As the largest, most established ETS in the world, and with its potential for mutual recognition with other cap-and-trade systems, the EU ETS forms the foundation for an eventual global carbon trading system (Ellerman et al. 2015). Some argue that the issues mentioned above indicate serious flaws in the system, while others say that the market is working as intended and that the allowance price will correct itself over time (Ellerman et al. 2015). Either way, the centralized regulation of the EU ETS does demonstrate the ability to alter regulations and structure over time to account for issues and concerns, and provides a valuable example for future carbon market development by having attempted many different strategies with varying levels of success.

Western Climate Initiative

The largest, most comprehensive GHG trading system in North America is the Western Climate Initiative (WCI). WCI is an international organization that exhibits cooperative inter-jurisdictional efforts similarly to the EU ETS, in which several independent jurisdictions work collaboratively to reduce GHG emissions, but with each jurisdiction developing its own targets to reduce GHG emissions (Klinsky 2013) as opposed to the centralized structure exhibited in the EU ETS. Since its inception in 2007, the WCI has contained 11 partner jurisdictions including 7 US states and 4 Canadian provinces, and is currently composed of 5 (British Columbia, California, Ontario, Quebec, Manitoba) (Klinsky 2013; WCI 2013). The overall goal of the WCI is to reduce emissions by 15% below 2005 levels by 2020 and to establish a multi-jurisdiction ETS (WCI 2013). Only 2 of the original 11 jurisdictions have successfully implemented ETSs to date, namely California and Quebec (Houle et al. 2015), with 2 more scheduled for implementation in Ontario and Manitoba (ICAP 2016).

Unlike the centralized structure of the EU ETS, the WCI market is composed of multiple independent trading programs in its member jurisdictions, with each state/province responsible for issuing emission allowances according to their own mitigation targets. The sum of these allowances serve as the cap of the WCI ETS, which is to be lowered every year. The system includes rigorous reporting requirements to ensure accuracy and timeliness, and provides a common central organization under which multiple markets can be connected (WCI 2010).

The first ETS to come out of WCI was the California ETS, which launched in 2012 and began its first compliance period in 2013 (ARB 2016). The goal of this system is to reduce emissions to 40% below 1990 levels by 2030 (Kossoy et al. 2015b; ARB 2016; Wara 2014). It operates as a cap-and-trade system, with the California Air Resources Board (ARB) regulating the distribution of allowances (Wang & Wu 2013), and has benefitted from the beginning by carefully observing the EU ETS and avoiding similar errors in design such as over-allocation of free allowances (Cullenward 2014). Offset credits from ARB-recognized projects may be used but may cover no more than 8% of the allowances issued per year (Wang & Wu 2013).

It is clear that emissions have decreased in California and that the program has contributed to innovation and entrepreneurship in clean energy and energy efficiency. Nonetheless, there remain mixed opinions on the success of this market (Cullenward 2014; Wara 2014). California's environmental success is not necessarily due to the cap-and-trade program, but instead is due to the implementation of a range of other environmental policies and regulatory programs, with the ETS acting more as a framework that ensures targets are met than the actual mechanism for decreasing emissions. These other environmental policies (including GHG tailpipe standards, the Low Carbon Fuel Standard, energy efficiency standards for buildings, and renewable energy mandates for utilities) are referred to as complementary policies to support the ETS, but in reality they facilitate the majority of emissions reductions (Cullenward 2014; Wara 2014). This suggests that although this climate policy is effective in California, it may not be an ideal climate market structure for other states to follow.

Some have warned of additional issues in California's ETS, which may represent a case of caution to other US states looking to California as a model of best climate policy practices (Cullenward 2014; Wara 2014). Although this market may appear, on the surface, to be effective in decreasing GHG emissions, it suffers from extreme cases of carbon leakage, as with any small scale ETS (Cullenward 2014; Wara 2014). An example of this comes from the company Edison, who, after implementation of the carbon market, sold its interest in the Four Corners Power Plant to an Arizona utility, thereby allowing the emissions to continually be emitted, while serving customers in Arizona as opposed to California (Cullenward 2014). The state law requires that California's ETS minimizes leakage, but the regulatory documents for the system do allow resource shuffling, including 13 "safe harbor" exemptions allowing leakage of emissions to these safe harbor coal power plants (Cullenward 2014). This represents the main weakness of California's market, as resource shuffling and leakage lead to a weak cap. California's market highlights the importance of regulating leakage, while also drawing attention to the need for a more expansive regional or international market to avoid such leakage. It is important to note that although this resource shuffling can undermine the emissions reductions that have occurred, the complementary policies in place in California are unaffected by a weak market cap and positive changes are therefore still occurring under this scheme (Cullenward 2014).

As for Quebec, this province launched an ETS in January 2013 and officially linked its system with California's in January 2014 (Government of Quebec 2009; Haites 2016), with the first shared auction taking place in November 2014 (Kossoy et al. 2015b). The primary goal of Quebec's ETS is to reduce emissions from the highest emitting sectors (including electricity and fuel), plus transportation, industry, and buildings, by targeting companies in the industrial and electricity sectors that emit 25,000 tCO_{2e} or more annually, as well as fossil fuel distributors (Government of Quebec 2009). The system is virtually identical in design to that of California's, with three compliance periods (2013-2014, 2015-2017, 2018-2020) and a cap that declines annually with a 1-2% decrease in the number of freely allocated credits (Government of Quebec 2009; Haites 2016).

Quebec is one of the lowest carbon emitters in NA due to investment in renewable energy sources including hydroelectric and wind, which provide 50% of total energy use and 98% of electricity in the province (Dahan et al. 2015). So far the ETS has been successful, with carbon prices remaining above CAD$10 ($15.14 in the first quarter of 2015), an 8% reduction in GHG emissions compared to 1990 levels in 2012, and raising money for the Green Fund (estimated $3.3 billion by 2020) to help finance a greener economy (Dahan et al. 2015).

This system includes three types of emissions allowances, all of which are interchangeable with California's allowances: (1) emission credits distributed for free, auctioned off, or sold, (2) offset credits from emission reductions in sectors not subject to the ETS, and (3) credits for early reductions (Government of Quebec 2009). Other examples of coordination between the two systems include regulatory provisions, offset protocols, joint auctions, mutual recognition of compliance instruments and a requirement for approval of the other party before linking with another ETS (Haites 2016). Both markets in California and Quebec were expanded to include transport fuels in 2015 and now cover 85% of California and Quebec's total GHG emissions (Kossoy et al. 2015b). The Californian system is much larger, with a cap of 334.2 million tCO_2e in 2020 in comparison to the 54.7 million in Quebec (Haites 2016), yet these markets provide a successful example of cross-border linkage.

Top-Down Carbon Markets

Switzerland

The Swiss ETS was originally implemented in January 2008 as an alternative option for complying with the national CO_2 levy on heating, industrial processes and transport fuels, where companies could pay the CO_2 levy or voluntarily participate in the ETS by setting an absolute emissions target (Haites 2016). Between 2008 and 2012, companies under the Swiss ETS were allowed to use Certified Emissions Reductions (CERs), Emissions Reduction Units (ERUs) and Removal Units (RMUs) under the KP to meet up to 8% of their compliance requirements, but actual emissions each year were still lower than the cap (Haites 2016). The system was restructured in 2013 under Switzerland's revised CO_2 Act to be similar to the EU ETS in order to facilitate linkage by having mutually recognized emissions allowances (Haites 2016; Federal Office for the Environment 2016). Approximately 5 companies, covering a total of 5.5 million tonnes of CO_2, currently participate in the Swiss ETS and Switzerland hopes to link this system with the EU ETS to create a joint market (Federal Office for the Environment 2016). Discussion and technical negotiation between the EC and the government of Switzerland has led to an agreement (pending ratification by both parties) for the Swiss ETS to be linked with the EU ETS (Federal Office for the Environment 2016).

Japan (Tokyo and Saitama)

Japan has taken a unique, smaller scale approach to carbon market development through the establishment of two city-sized markets in Tokyo and Saitama, unilaterally linked together. In April 2010, the Tokyo Metropolitan Assembly launched the first ever mandatory cap-and-trade system in Asia (Haites 2016; Rudolph & Kawakatsu 2012). The TMA (Tokyo Metropolitan Area) ETS is a mandatory CO_2 emissions control scheme that sets binding targets to buildings and covers 1,400 installations of office and commercial buildings and factories, encompassing commercial and industrial sectors (Haites 2016; Roppongi et al. 2016). The cap for participating facilities was set at 6% below baseline emissions (average of 3 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 similar to that of the Swiss ETS, of 10.44 million tCO_2 in 2020 (Rudolph & Kawakatsu 2012; Roppongi et al. 2016).

The TMA ETS is unique from other carbon markets in many aspects and demonstrates numerous effective approaches that can and should be implemented elsewhere (Rudolph & Kawakatsu 2012;

Roppongi et al. 2016). The system is regarded as successful, as it has led to significant reductions in CO_2 emissions including a 23% reduction in emissions from the base-years by the end of 2013, with 90% of facilities achieving their first reduction target and 69% of them already meeting their 2019 target (Roppongi et al. 2016). The policy effectiveness of this system can be explained by many factors, including leadership and administrative capacity, stakeholder involvement in policy formulation and implementation, availability of data to support policy decisions, gradual implementation, no free allocation of tradeable credits, transparent monitoring, and focus on energy consumers rather than entities within specific sectors (Rudolph & Kawakatsu 2012; Roppongi et al. 2016). Many of these design factors are unique to this ETS and demonstrate the effectiveness of a compulsory monitored cap operating under strict regulations (Roppongi et al. 2016).

A decade-long dataset of industrial activities and existing reduction plans was used to create a detailed policy design targeted to local conditions in Tokyo, which was a fundamental way to induce collective action and gain stakeholder acceptance of this ETS (Roppongi et al. 2016). Similarly to the EU ETS, the system was gradually implemented over 3 main phases, beginning in 2000 before the first compliance period in 2010, with the longest compliance assessment of all ETSs, conducted over a five year period in order to allow for long-term planning and goal setting (Roppongi et al. 2016). Although emissions rights are grandfathered to participating entities at the beginning of each compliance period, emissions allowances alone cannot be traded in the market, as tradable credits are only earned by the owner fulfilling their own reduction targets and making additional reductions within the compliance period that are verified by the designated authority (Roppongi et al. 2016). Transparency and consistent enforcement of effective monitoring is fundamental in the high compliance and success of this system, as MRV follows strict and reliable procedures that include external verification (Rudolph & Kawakatsu 2012), as opposed to the weak MRV mechanisms in the Chinese ETSs. The final key characteristic of this ETS includes the targeting of energy-related CO_2 emissions from large business facilities (that consume more than 1,500kL of oil equivalents annually) instead of taking a sectoral approach, as these types of emissions account for 95% of all GHG emissions in Tokyo (Roppongi et al. 2016).

An ETS very close in design to Tokyo's was established in Saitama in April 2011 and is linked to the TMA ETS through compatible emission reduction credits, with credits becoming tradable between the two jurisdictions in 2015 (Roppongi et al. 2016; ICAP 2016). This system is run by the Saitama Prefectural Government, with the first phase occurring from 2011-2014 and the current phase from 2015-2019. This system has the same compliance periods, inclusion thresholds, allocation, and emissions baseline as the Tokyo scheme. This system is likewise considered to be a success, as it achieved a 22% reduction in emissions below base-year emissions by 2013 (ICAP 2016).

One common issue that must addressed in both of these systems, as in the WCI ETS, is the risk of carbon leakage due to the small scale of the current schemes (Roppongi et al. 2016). Also, despite the success of these ETSs, there is still no political consensus on the future of national climate policy in Japan and the implementation of a national-level ETS. Japan's INDC states that the country aims to reduce national emissions to 26% below 2013 levels by 2030, but makes no mention of a national carbon market (UNFCCC 2015), unlike the recent promises of China to implement a national carbon market.

Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort amongst 9 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 (RGGI Inc. 2016; Fell & Maniloff 2015). The RGGI began in 2009 and represents the first mandatory, market-based CO_2 emissions reduction program in the US (RGGI Inc. 2016; Haites 2016). The system includes 3 compliance periods (2009-2011, 2012-2014, 2015-2017) (Haites 2016; Kopsch 2016), with a new cap of 91 million tonnes implemented in 2014 to be decreased by 2.5% per year (RGGI Inc. 2016; Hibbard et al. 2015), and a relatively ambitious goal of a 50% reduction in emissions below 2005 levels by 2020 (ICAP 2016). Unlike the WCI, this system only targets the power sector (fossil fuel plants that are 25MW or more in size) and has centralized administrative infrastructure system called RGGI Inc. (a non-profit organization) to help implement the program and conduct central auctions of allowances quarterly (Hibbard et al. 2015; Kopsch 2016), as well as the use of a common compliance instrument (Haites 2016). Similarly to WCI, however, each state's environmental regulatory agency serves as the main administrative authority and regulates an individual emissions cap (Centre for Climate and Energy Solutions (C2ES) 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). The system does allow for the use of international offsets if the price of permits exceeds a specified level. Although that required level has not yet been reached, this does provide potential for international linkage in the future (Haites 2016).

A main concern with the RGGI (as well as the WCI and the two subnational Japanese ETSs) is carbon leakage, due to the nature of regional emissions reduction policies. RGGI, however, is a unique case in which leakage may actually be environmentally beneficial, as it has led to a shift in production to relatively cleaner producers (Fell & Maniloff 2015). Although about 25% of apparent emissions reductions from RGGI have been estimated to have been leaked, this has led to a reduction in the total combined emissions of an additional 1% due to the leaked electricity generation in non-capped jurisdictions being less emissions intensive (Fell & Maniloff 2015). Along with leakage, RGGI also allows power to be imported to regulated regions without being subject to the emissions cap or any border adjustments (Fell & Maniloff 2015). Such conditions imply that emissions from power production within RGGI states may be reduced, however not necessarily the overall use of power generating emissions elsewhere.

An important positive characteristic of this system is that, unlike the EU ETS, RGGI has a price floor for the auctioning of credits, meaning that although permit prices have dropped quite low, the price floor prevents a complete price collapse (Fell & Maniloff 2015). This characteristic was adapted due to lessons learned by the collapse of the Chicago Climate Exchange (CCX) in 2010, and should subsequently be implemented in other ETSs threatened by low allowance prices, such as New Zealand and China. RGGI, like the WCI and more broadly the EU ETS, 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 US and Canada, both of which currently lack a national pricing instrument, in part contributing to the uniqueness of this ETS (C2ES 2013; Kossoy et al. 2015b).

South Korea

The Republic of Korea launched a unique national ETS in January 2015 with the first phase spanning from 2015-2017 and plans for phases 2 and 3 from 2018-2020 and 2021-2026 (Sopher & Mansell 2014; Hawkins & Jegou 2014). This ETS displaced the previous Target Management System (TMS), which was adopted in 2010 and set a target for emissions reductions from private and public entities without the option of trading credits, acting as a precursor to the ETS (Sopher & Mansell 2014; Park & Hong 2015). The ETS is run by the Emission Allowance Allocation Committee under the Ministry of Strategy and Finance, as well as the Ministry of Environment (Park & Hong 2015). The country aims to reduce emissions by a mere 4% below 2005 levels by 2020 and the ETS is expected to be the key policy instrument to achieve this goal (Sopher & Mansell 2014; Park & Hong 2015).

The threshold for mandatory capped entities are companies that annually discharge 125,000 tCO_{2e} or facilities that emit more than 25,000 tCO_{2e} per year (with the average emissions over the 3 year period prior to the beginning of phase I being used to determine participation), while others can participate voluntarily (Sopher & Mansell 2014; Park & Hong 2015; ICAP 2016). Capped entities include 23 industrial, power and aviation subsectors, covering 60% of the country's emissions (Kossoy et al. 2015b). This scheme includes all 6 KP GHGs and 7 sectors of the economy (industry, transportation, buildings, public, agriculture/fishery, waste and power) (Park & Hong 2015). The national cap and allowance allocation standards are specific to the phase, industry and sector, with 100% of allowances freely allocated in phase I, 97% in phase II and 90% in phase III (Sopher & Mansell 2014). The system allows a maximum of 10% of allowance obligations to be met using offset projects, with the use of international offset credits excluded until 2020 (Sopher & Mansell 2014). Allowances can be banked for one year between phases, and allowances can be borrowed from years within the same phase. A unique feature of this system is that early reduction will be credited in the form of additional allowances of up to 3% of the total emission volume (Sopher & Mansell 2014). The system does have price control mechanisms that may include additional allocation from an allowance reserve, similar to the ex-post adjustment method used in the Chinese pilot systems, in case of excessively high carbon prices (ICAP 2016).

In contrast to the issues faced in the EU ETS, the South Korean market is undersupplied and companies are reluctant to sell their allowances, with the low cost of international offset credits leading to a demand for offset projects in the country (Kossoy et al. 2015b). This system has also faced extreme confrontation and criticism, as many stakeholders argue that the ETS imposes a burden on South Korea's national economy (Heo 2015). One key compromise upon launch of the ETS was to agree to 100% free allocation of allowances in the first phase (Heo 2015; Sopher & Mansell 2014). South Korea has expressed interest in international linkage with other ETSs such as Europe or Australia, but serious discussion of such linkage won't occur until phase 2 (Sopher & Mansell 2014).

Bottom-Up Carbon Markets

China

China is the largest GHG emitter in the world, and as such, is faced with large external pressure to reduce emissions as the country plays a crucial role in the success of global efforts to address climate change (Liu et al. 2015). A carbon-trading market is a promising option for the country to meet its 2020 goal of reducing carbon intensity by 40-45% below 2005 levels, as a market approach can effectively target the energy sector and provide the necessary means to meet this goal at minimal cost while balancing a growing GDP (Liu et al. 2015; Wang 2016). The high consumption of coal in China will contribute to the challenge of meeting this goal, with estimations that coal will still account for approximately 63% of energy consumption in China in 2030 (Liu et al. 2015; Zhang et al. 2014), making carbon trading a necessary step towards meeting its 2020 reduction goal. China has experimented with carbon markets in the past, with the CDM providing a positive channel for introducing the concept and practice of carbon trading to the country (Liu et al. 2015). China has since become the world's largest supplier of CERs, accounting for 43.52% of CDM carbon credits, but with exclusively buyers from outside of the country (Liu et al. 2015). At the end of 2011, the Chinese government selected 7 areas (5 cities and 2 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 an effective national carbon market in 2017 (Liu et al. 2015; Swartz 2016).

The priority of the Chinese system is economic development (Zhang et al. 2014), and in order to ensure environmental benefits are not disregarded in preference for economic benefits, components of the current Chinese system that favour economic development should be addressed. This includes re-allocation of emission permits, free allocation of permits, and over-allocation of permits. China's perspective on carbon markets as an economic development opportunity is an important barrier to consider in developing an international market with environmental integrity.

Current pilot ETSs

Prior to attempting national carbon trading, the National Development and Reform Commission (NDRC) authorized 2 provinces (Guangdong and Hubei) and 5 cities (Beijing, Shanghai, Tianjin, Shenzhen and Chongqing) at different levels of economic development to incorporate carbon emission trading between enterprises with high energy consumption and emissions in October 2011 (Liu et al. 2015; Wang 2016). All pilot jurisdictions operate independently (Pang et al. 2016) and were required to submit proposals for their own carbon-emission targets and detailed implementation plans by the end of 2012. Local governments were in charge of structuring and administering the ETS including determining the cap, means of capping, and the capped sectors (Liu et al. 2015). By the end of 2014, all seven pilot systems had been launched (Liu et al. 2015), and as of July 31, 2015, over 57 million tCO_2 had been traded under these systems, with a total value of USD$308 million (Swartz 2016).

These 7 pilot ETSs cover a large geographic area (over 481 thousand km) and population (over 260 million people), including 20% of the country's energy use and 16% of CO_2 emissions (Wang 2016), representing cumulative emissions of 1.5 billion tCO_2 in 2010 (Wang 2016). In general, these pilot jurisdictions are located in relatively highly developed regions exhibiting low emissions intensities and higher per capita GDP than the national average (Wang 2016; Zhang et al. 2014). The pilot locations have different levels of economic development, industry and energy structures, energy efficiency, and potential for and cost of carbon reduction (Pang et al. 2015). Shenzhen was the first ETS established in June 2013, with Chongqing being the last in June 2014 (Wang 2016). The pilot system with the lowest carbon intensity (Shenzhen) is 0.6 tCO_2/k$, twice as small as the highest jurisdiction (Hebei) at 1.4 tCO_2/k$ (Zhang et al. 2014). All systems set a target of between 17 and 21% reduction from 2010 levels by 2015 (Wang 2016).

The systems differ in extent of sectoral coverage, size of threshold for qualifying installations, and other design features depending on local characteristics and priorities (Zhang et al. 2014). Thresholds for coverage differ greatly between the regions, with Hubei having the highest (60,000 tce per year) and Shenzhen having the lowest (5000 tCO_2 per year) (Wang 2016). All pilot systems include heat and electricity production, iron and steel, nonferrous metals, petrochemicals and chemicals, paper and cement, with some differences in sectoral coverage across systems (Wang 2016; Zhang et al. 2014). Shenzhen, for example, has implemented the broadest sectoral coverage, including all industrial and building sectors (Wang 2016). Sectoral coverage decisions were made in order to ensure a large share of emissions are covered while maintaining a manageable number of entities (Zhang et al. 2014). The GHG emissions coverage ranges from 33% of emissions in Hubei to 60% in Tianjin, as does the price of carbon from USD$4 in Hubei, Tianjin, and Chongqing and USD$8 in Beijing (Kossoy et al. 2015b). Enterprises in these pilot markets 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). Virtually all permits are freely allocated by grandfathering (based on enterprise's historical emissions or expected future requirements) or by benchmarking (based on a specifically defined benchmark of emissions) (Duan et al. 2014), aside from a small number auctioned in Guangdong, Shenzhen, Beijing and Hubei, in order to decrease the burden on enterprises and encourage economic development (Zhang et al. 2014; Wang 2016; Duan et al. 2014). Although auctioning is a more economically efficient method of allocation, it provides enterprises with increased costs and therefore has low political acceptance (Pang & Duan 2015).

Two unique and important characteristics of China's system is the cap setting approach and the allocation method. The pilot systems generally use a bottom-up, two-step approach for cap setting by first projecting their emissions in 2015 and then dividing that overall emissions into the trading system cap and non-trading system cap, while considering issues such as sectoral growth (Duan et al. 2014). These caps are often intensity-based caps that use projected GDP growth and emissions targets, as opposed to absolute emission caps established in other carbon markets such as the EU ETS. Although the pilot system caps are not technically intensity caps, they can be considered to be due to their link to overall national intensity targets. Once the cap is set, allowances are allocated using the methods mentioned above, but depending on the sector, there are four different methods of permit allocation (Duan et al. 2014). Allocation can be done through grandfathering with or without ex-post adjustment, or through benchmarking with or without ex-post adjustment. This ex-post adjustment factor is an important aspect of the pilot ETSs and refers to the addition or removal of emission allowances after the compliance period if actual emissions vary greatly from the predicted level. Ex-post adjustment is used mainly in the electricity and heat generation sectors to accommodate for the tight market regulation (Pang & Duan 2015). This leads to a flexible cap that can be adjusted when necessary due to the bottom-up approach of aggregating allowances allocated to participants to create the cap (Pang & Duan 2015). The flexible cap also allows the government to adjust supply according to demand and therefore form a more stable carbon price (Pang & Duan 2015). Intensity targets, flexible caps, and ex-post adjustment are used in order to decrease uncertainty regarding the cost of emissions reductions, moderate market volatility, avoid steep prices changes, reward enterprises that have low carbon intensity and protect enterprises that provide an essential public service (Wang 2016; Pang & Duan 2015). Along with this complex system, each pilot system has designed its cap differently, with Beijing, Shanghai, Tianjin and Shenzhen keeping their cap unchanged, while Hubei increases its cap between years to accommodate economic growth and Chongqing reduces its cap each year like a traditional cap-and-trade system (Xiong et al. 2015).

These unique characteristics implemented in the Chinese ETSs are a result of unique challenges that China faces in developing a carbon market, such as fast but uncertain economic development, a national intensity target (emissions per GDP) instead of an absolute carbon target, and tight regulation of pricing by the government, particularly in the electricity and heat generation sectors (Pang & Duan 2015). Some of these sectors have very large enterprises composing the majority of emissions and are managed by highly ranking administrators that can affect decision-making processes in the region (Pang & Duan 2015). Due to the rapid changes in economic output, lack of transparent production information and incomplete emissions data, there is often a large discrepancy between allocated allowances and actual emissions, which is why these measures are deemed necessary to prevent a large shortage or surplus of allowances in the market (Xiong et al. 2016). Given these challenges, a flexible cap and ex-post adjusted allocations are better accepted by enterprises and economic authorities, although these strategies need to be reexamined carefully in development on a national system, as they provide questionable environmental benefit and will lead to higher social abatement costs in the future (Pang & Duan 2015).

There are a number of issues with China's ETS design that have become evident over the years of pilot implementation (Xiong et al. 2016). Issues faced by these pilot systems include absence of a functional carbon trading market due to strong government control, price control systems in some sectors that cause distortions in the financial sector and make implementation of a market-based approach challenging, inaccuracy in quota allocation due to inaccurate or inexistent historical records, an imperfect trading mechanism which restricts the products that can be traded and keeps the price of carbon in China below the international market price (Liu et al. 2015). High allowance allocation due to the use of historical emission intensities present an additional issue, as allocation is based on emissions intensities which are based on a previously higher GDP than the current "new normal" GDP in China's economic slowdown (Xiong et al. 2016). Another issue to confront is the lack of legislation, which is lagging behind in terms of emission rights, trading rules, monitoring, collection of emissions data, verification, enforcement and penalization for non-compliance, and similarly, the lack of a regulatory system run by a unified emissions management institution. China's carbon trade is currently led by the National Leading Group on Climate Change, managed by the NDRC, however this group is focused on CDM with little experience and concrete rules to sufficiently manage a national system (Liu et al. 2015). These issues will lead to significant problems in implementing a representative carbon price to trade in the international market (Liu et al. 2015).

Future national ETS

The 7 pilot ETSs will transition into a national ETS as part of China's 13th Five-Year Plan from 2016-2020 (Swartz 2016). The national ETS is to be based on the best designs and practices of the pilot systems (Swartz 2016; Pang & Duan 2015). China has become the world's second largest carbon market after the EU (Peng et al. 2015). To appreciate the size of China's market and market potential, in a single pilot area, Guangdong, the size of the market ranks second biggest next to the EU, controlling 0.388 billion tCO_2 in 2013 (Liu et al. 2015). The national market is expected to cover 16% of national GHG emissions, including 8 sectors and 18 sub-sectors that consume over 10,000 tons of coal equivalents per year and 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 Chinese carbon market could determine the fate of the international carbon trade and holds a large degree of responsibility in the international community to make careful decisions regarding their carbon market and linkage (Liu et al. 2015). Establishing a national ETS in China will have major international implications for climate policy and substantial influence on current international carbon trade (Swartz 2016). Linking with China's current intensity-based ETS would require trading restrictions (Swartz 2016).

The current market design and management of the Chinese ETSs has many inadequacies, and the country will face many challenges in establishing a responsible, effective and functional national system (Peng et al. 2015). Issues that may inhibit development of an effective national system include a lenient design, conservative allowance allocation that is incompatible internationally, poor information transparency, an imperfect trading mechanism and lagging legislation (Liu et al. 2015; Peng et al. 2015). National ETS development will likely face many challenges in ensuring compliance and enforcement, applying uniform rules on MRV across the country, reducing absolute emissions under the intensity target of the Paris Agreement, preventing over-allocation of allowances, and avoiding low liquidity (Swartz 2016). Another major challenge will be enforcement and compliance, which will likely fall on NDRC and MRV will be a challenge due to the size of the system (Swartz 2016).

Recommendations for development of a national ETS include using a reverse verification method for allowance allocation to minimize the risk of excessive allocation, creating a unified national platform for trading, and developing legislation and a related independent regulatory department for carbon trading to maintain order in the market (Liu et al. 2015). Future development of a national ETS in China would need to ensure that its goals are in line with national climate change objectives, focus on emissions reductions in the production sectors, and take into account unbalanced regional development (Peng et al. 2015). National legislation that emphasizes climate change mitigation should be developed as soon as possible, and transparent independent reporting of emissions is crucial (Zhang et al. 2014). The cap is key to ensuring environmental integrity and maximizing the participation of as many sectors as possible will help to ensure liquidity (Swartz 2016). The national ETS will require a strong compliance and enforcement plan, need to address the risks of carbon leakage while remaining open to market linkage, and avoid overlapping environmental policies in the country to maximize its effectiveness (Swartz 2016). It is also advised that the government implements a top-down, centrally controlled national market, as opposed to an attempted linkage of the 7 existing pilot markets, as coordinating linkage of the currently very different pilot systems would require tremendous effort and modification (Pang et al. 2015; Zhang et al. 2014). The national ETS should be a unified national system with a uniform scheme and rules built and regulated at the national level (Pang et al. 2015). China should also increase the amount of allowances that are auctioned to avoid free allocation, and the timeliness and transparency of information (including rules and regulations) should be improved for the country to establish a successful national system (Xiong et al. 2016).

The current development of carbon markets in China demonstrates that the Chinese government is taking action and planning to contribute to development of an integrated international market (Liu et al. 2015). Issues revealed by the pilot systems that have been mentioned here and elsewhere in the literature should be thoroughly assessed before launching a national market to ensure it is as robust and effective as possible (Xiong et al. 2016). If done properly, national market development in China and international linkage could help support the achievement of the Paris Agreement targets (Swartz 2016). By developing a national ETS, China can send a signal to other large economies that carbon pricing is an important part of future climate policy (Swartz 2016).

New Zealand

New Zealand's ETS was launched in 2008 and is currently the only carbon market with plans to include all sectors of the economy (ICAP 2016; Diaz-Rainey & Tulloch 2015; Haites 2016). Compliance obligation was phased into this system from 2008 to 2015, with mandatory participation for companies that exceed sector-specific emissions thresholds (Haites 2016). All sectors were meant to be phased in by 2013, but official entry of the agricultural sector has been delayed indefinitely, with no mention of the issue in the country's INDC (Diaz-Rainey & Tulloch 2015; Adams & Turner 2012; UNFCCC 2015). The forestry sector is included in the system and is currently expected to report emissions, although is not yet obligated to reduce them (ICAP 2016). Nonetheless, the inclusion of forestry and the planned inclusion of agriculture is unique to this ETS and is significant. Under this scheme, forest landowners receive carbon credits for forestry activities that lead to sequestration and are also liable for the release of carbon when harvested (Jiang et al. 2009; Tee et al. 2014).

New Zealand's ETS is a cap-and-trade system (similarly to the EU ETS and WCI) under which participants can buy credits at a fixed cost from the NZ government or at market prices from the market (Tee et al. 2014), and uses intensity-based allocation of allowances to the industrial sector (90% free to high emissions-intensive industry and 60% to moderate intensity) (ICAP 2016). The goal of the system is to aid New Zealand in its transition to a low emissions economy and decrease GHG emissions to 30% below 2005 levels by 2030 (ICAP 2016; UNFCCC 2015). This ETS was originally designed to be linked with international offsets with no restrictions on the use of credits, however due to the oversupply of international emission credits leading to a lower cost than domestic New Zealand Units (NZUs), the country no longer allows KP-related credits to be traded within its ETS (as of June 2015) (Kossoy et al. 2015b). The country has stated that they will reassess the use of international credits once international market conditions are more in line with the domestic situation (Kossoy et al. 2015b) and international market access is stated as a priority in New Zealand's INDC (ICAP 2016).

New Zealand's ETS is unique in design and not easily comparable to other ETSs, although it has seen success, leading to an increase in afforestation, improved silvicultural practices and reduction in emissions due to displacement of agriculture (Adams & Turner 2012). The effectiveness of this system has been a topic of debate, however, as NZU prices have been low, in part due to a liberal allocation policy and due to the previously unlimited use of international offset credits (Diaz-Rainey & Tulloch 2015).

India: Perform, Achieve, and Trade

India is known to be reluctant to participate in international climate policy, as the country generally views climate change as a problem caused by developed countries and fears a global ETS could hinder national economic development (Virmani & Rao 2015). The country does, however, have two independent and unique systems that resemble emissions trading in order to support its own sustainable development: Perform, Achieve and Trade (PAT) and Exchange Traded Scheme (ETS)

(Virmani & Rao 2015). Of these, PAT is currently in operation and plays an important role in India's INDC (UNFCCC 2015).

PAT sets mandatory energy efficiency targets for the most energy-intensive industries (thermal, power, iron and steel, cement, fertilizers, textiles, aluminum, pulp and paper, and chloralkali in the first phase, with the railway sector to be implemented in the second phase), under which energy savings certificates can be traded to achieve energy intensity targets (Virmani & Rao 2015). Although this system does not involve direct trading of CO_{2e}, the "potential unit of energy saved" credits used in this market could be converted to CO_{2e} credits. PAT's first compliance period took place from 2012 to 2015, within which energy efficiency measures aimed to reduce emissions by 26 million tCO_{2e} and to save 6.6 million tonnes of oil equivalents (Virmani & Rao 2015). PAT covered 478 plants (called designated consumers) in 8 sectors in 2015 and has led to a decline of 5% in specific energy consumption between 2012 and 2015 (UNFCCC 2015). Participating facilities are obligated to improve energy efficiency by 1-2% per year, varying with circumstances (emissions baselines are determined as the 2007-2010 average and energy efficiency targets are measured by specific energy consumption) (Virmani & Rao 2015).

PAT is regulated by the Bureau of Energy Efficiency (BEE) and the Central Electricity Regulatory Commission (CERC) (BEE 2016). Although not directly linked to other carbon markets, the PAT mechanism does lead to carbon emissions reductions as a consequence of energy savings and is linked to the international market through offset-based financing under CDM. This market also serves as a potential foundation for creating a more holistic ETS in India. The first phase is now complete and, according to the country's INDC, is expected to continue and to cover more than half of the commercial energy industry in India in phase 2 (UNFCCC 2015).

It should be noted that while China and India are employers of a bottom-up carbon market approach, New Zealand similarly employs this approach. China and India are considered developing countries and this bottom-up methodology allows for flexibility in their emissions caps. New Zealand, on the other hand, is a developed country and should be transitioning its ETS into an absolute, top-down trading system as a means to sufficiently limit emissions and address climate change. A bottom-up approach to emissions trading, although less environmentally effective, may be the most practical way for developing, impoverished countries to contribute to climate change mitigation, and may provide a reasonable means for developing countries to join an international carbon market in the future.

Dissolved, Discontinued, and Suspended Carbon Markets

Chicago Climate Exchange

The Chicago Climate Exchange (CCX) is an example of a cap-and-trade market created primarily 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 (Gans & Hintermann 2013). The CCX began operating in 2003 and ended in 2010. During this time, credits for all GHGs covered under the KP were tracked as Carbon Financial Instruments (CFIs), each CFI accounting for 100 tCO_{2e} (Gans & Hintermann 2013; Yang 2006). At the time of inception, CCX included 28 members accounting for about 700 million tCO_{2e} annually (Yang 2006). Members agreed to reduce their emissions by 1% each year below the baseline average (1998-2001) in phase 1 (2003-2006), and further cut emissions by 0.5% each year in phase 2 (2007-2010) (Gans & Hintermann 2013). Benefits of participating included positive public relations and environmental benefits, preparing for emissions regulations prior to the implementation of mandatory government legislation, procuring a profit by selling extra credits, as well as complying with KP regulations if partaking in business with countries committed to the treaty. Although a voluntary market, the CCX included strict provisions and standards for auditing of emissions reductions, as well as a formal market for purchasing of abatement credits, making it similar in many ways to a mandatory market. The emission reduction objectives of members were also legally binding, even though membership was voluntary (with a membership fee ranging from $1,000-$35,000 per year depending on the type of membership and size of the firm) (Gans & Hintermann 2013).

The CCX was discontinued at the end of 2010 due a collapse in the exchange price of CFIs (Gans & Hintermann 2013; CORE 2011). The collapse of this system has since influenced the structural design of other markets, such as RGGI, as the CCX is a valuable example of the need for a price floor and should further be adapted by ETSs threatened by low allowance prices. CCX exchange prices decreased to $0.05 per CFI due to a large influx of credits from offset projects such as energy efficiency projects, fuel switching projects, renewable energy projects, bio-sequestration through forestry and agricultural management practices, etc. (CORE 2011). Failure of the CCX placed the legitimacy of the system and its reporting and verification of offsets in question. This system emphasizes the importance of a realistic emissions cap value and strict regulation of offset credits to ensure integrity, which is especially important for the EU to consider in order to avoid collapse of its ETS, as a similar drop in allowance prices is occurring in this system.

Pacific Carbon Trust

British Columbia (BC) has taken a very different approach to carbon market development than the rest of North America, using a carbon tax as opposed to a cap-and-trade market. BC established a Crown corporation called the Pacific Carbon Trust (PCT) in 2010 to trade carbon offsets (PCT 2014). The goal of the PCT was to reduce BC emissions and help to develop a low-carbon economy and a carbon-neutral public sector (PCT 2014). As such, public sector organizations were required to make offset payments through the PCT for their emissions at a fee of $25 per tCO_{2e}, in addition to BC's carbon tax (Lee 2011). The PCT is said to have reduced BC emissions by 3,014,666 tonnes between 2010 and 2013 (PCT 2016).

The PCT was dissolved in November 2013 and its functions were transferred to the Climate Action Secretariat in the BC Ministry of Environment (PCT 2014, 2016). The corporation was dissolved due to public concern about the funds being taken from public services, as well as questions about the credibility of 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 (Harrison 2013). This meant that decreases in public services that disproportionately benefit the poor were being used to subsidize private sector projects that cater to the affluent. 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 PCT offset credits for preserving tress that were not likely to be logged regardless of PCT funding, and fuel-switching projects that had been approved before establishment of the PCT received funding (Doyle 2013). Additionally, there was a lack of criteria to evaluate whether sufficient actions were being taken by the PCT to reduce emissions (Doyle 2013), and it was a combination of such conditions that caused the public to question the integrity and effectiveness of this system and led to its dissolution.

Kazakhstan

The Kazakhstan ETS was launched in January 2013 (ICAP 2016; Swartz & Upston-Hooper 2013) as a mandatory ETS including only CO_2 in the energy, mining and chemical industry sectors (not including agriculture or transport), with an overall objective to reduce emissions to 15% below 1992 levels by 2020 (ICAP 2016; USAID 2015). With the launch of this system, Kazakhstan became the first country in Asia to implement an economy-wide trading scheme. Although the system may be open to international collaboration, it currently cannot participate in CDM as an Annex I country under the KP (USAID 2015). The threshold for inclusion is 20,000 tCO_2 per year and allocations are done freely through a grandfathering approach. Phase 2 included 166 companies and around 150 $MtCO_2$, and phase 3 (2016-2020) is meant to include 131 companies (USAID 2015). However, with a new incoming government in 2016, Phase 3 has been suspended for 2 years (until 2018) by Vice Energy Minister Asset Magauov (Climate Policy Observer 2016). Details on the suspension are not yet public, but speculation indicates that the suspension is due to industry protests about the strict requirements and weak legal foundation of the system under the current national economy (Climate Policy Observer 2016).

India: Exchange Traded Scheme

India's ETS is a domestic market-based policy where a pollution target is set based on ambient air quality and emissions reductions certificates are traded in order to achieve absolute emissions reductions (Virmani & Rao 2015), with the ultimate goal of improving air quality (Kavitha et al. 2015). Three pilot states implemented this system in February 2011, Gujarat, Tamil Nadu, and Maharashtra (Virmani & Rao 2015; CPCB 2013). The goal of the pilot phase was to develop instrumentation and monitoring standards to expand the ETS to more states (Virmani & Rao 2015; CPCB 2013). The ETS is regulated by the Central Pollution Control Board (CPCB) and the relevant State Pollution Control Board (SPCB), who distribute emissions permits to capped facilities, and baseline setting and verification relies on a continuous emissions monitoring system (CEMS) (Virmani & Rao 2015). Unique to this trading mechanism is that the emissions targeted are particulates such as SO_2, NO_x and SPM. These particulates are harmful to human health and represent arguably the most challenging environmental problem in India, as particulate air pollution in this country is amongst the highest in the world (Virmani & Rao 2015; CPCB 2013; Michael et al. 2016).

This ETS sought to regulate pollution by industry for three main reasons: these point sources of particulate matter (PM) emissions lead to high levels of pollution at industrial sites compared to other parts of the cities; industries produce fine particles (Respiratory Solid Particulate Matter, RSPM) that are most damaging to human health; and monitoring emissions from a point source is much more realistic and effective than monitoring thousands of vehicles and cooking fires (Michael et al. 2016). In the case of this ETS, the PM pollution selected has a localized effect and no significant global impact, so expanding the system nationally would need to involve regulation of localized trading platforms (Kavitha et al. 2015). This ETS does have the potential, however, to provide the foundation for a CO_2 trading system in India that could eventually be linked internationally (Virmani & Rao 2015). However, after the pilot phase ended in 2015, there has been no mention of continuation and this system is not mentioned in the country's INDC (UNFCCC 2015).

Discussion of Future Markets

North America

In addition to ETS operations in California and Quebec, Ontario and Manitoba have plans to implement an ETS, and Washington State and Oregon are also considering the implementation of an ETS. The Governor of Washington State announced the implementation of a regulatory cap on GHG emissions in July 2015, and the Oregon House and Senate are currently debating bills regarding the topic (Kossoy et al. 2015b). Ontario also announced, after signing a Memorandum of Understanding with Quebec to collaborate on the market mechanism and releasing a draft regulation for a cap-and-trade program that follows the model of the WCI in April 2015, its intention to implement an ETS that is linked to that of California and Quebec (Kossoy et al. 2015b; Environmental Registry 2016; Haites

2016). With the first compliance period operating from 2017 to 2020, industries subject to the program will be those with annual emissions above 25,000 tCO_{2e}, natural gas distributors, electricity importers and petroleum suppliers. The plan states that allowances will be distributed initially at levels comparable to current emissions, but that regulated entities would gradually be required to reduce emissions or purchase allowances over this period (Environmental Registry 2016). Similarly to Quebec and California, offset credits will be used to cover up to 8% of compliance obligations and revenue from the market will be used for provincial initiatives such as renewable energy sources, transportation and infrastructure, and development of low carbon technologies (Environmental Registry 2016).

Recent political discussions suggest the potential development of a national ETS in Canada and the US, as well as potential linkage between the two. Political discussion on climate change in Canada has focused on the development of a nationwide carbon market and low carbon economy, with Prime Minister Trudeau committing in March 2016 to transition to a low carbon economy, including the use of a national price on carbon (Government of British Columbia 2016). The primary agreement made at the First Minister's Meeting in Vancouver was to reduce Canada's GHG emissions by 30% below 2005 levels by 2030. Agreements related to the development of a national carbon market include better coordination of GHG emissions reporting systems among jurisdictions to allow for the accurate, transparent assessment of progress, adoption of a carbon pricing mechanism, working towards enhancing carbon sinks including agriculture and forestry, and establishing an offset protocol framework within which carbon credits can be traded internationally (Government of British Columbia 2016). These discussions amount to an agreement to develop a pan-Canadian framework on clean growth and climate change, which is to be finalized in the fall of 2016 and implemented by early 2017 in order to inform the development and submission of Canada's INDC under the Paris Agreement. The Clean Power Plan, finalized by the United States Environmental Protection Agency in August 2015, is another potentially positive step towards a larger carbon market in North America. This plan allows states to choose their own compliance mechanisms for reducing power sector emissions, including emissions trading, efficiency measures and renewable energy, providing resources for California and RGGI states to meet their emissions targets (Kossoy et al. 2015b).

Recent discussions between American President Barack Obama and Canadian Prime Minister Justin Trudeau didn't explicitly state the development of a linked carbon market, but did generate the possibility of one through combined efforts to reduce GHG emissions (Justin Trudeau Prime Minister of Canada 2016). Outcomes of this discussion related to potential carbon market development include commitment to reduce methane emissions from oil and gas sectors by 40-45% below 2012 levels by 2025, agreement to use similar values for the cost of carbon and other GHGs when assessing regulatory measures, and expression of strong commitment to reduce emissions from international aviation in part through a carbon offset measure (Justin Trudeau Prime Minister of Canada 2016).

Australia

Climate policy in Australia has undergone many changes along with changes in government power. Its ETS didn't pass through government in 2011, and instead a carbon tax has been in place. A carbon tax was implemented in July 2012, covering 60% of Australia's GHG emissions from fuel use in electricity generation and industry, fuel distributors, industrial processes, mines and waste (Jotzo 2012; Chan 2015; Robson 2014). The tax began at AUD$23 per tCO_{2e}, with plans to increase by 5% per year until 2015, when it would transition into a full ETS with the tax changing to a floating price set by the carbon market after three years of fixed pricing (Jotzo 2012; Zakeri et al. 2015; Robson 2014). This tax differed greatly from the BC carbon tax in that it applies to emissions of 4 different GHGs (CO_2, CH_4, NO_2 and PFCs) and applies to facilities that meet the 25,000 tCO_{2e} threshold of emissions per year, with comprehensive sectoral coverage, not including agriculture, forestry, or combustion of biofuels and biomass (Robson 2014). Essentially, the Australia carbon tax was designed and implemented to eventually convert into an ETS (Robson 2014), until it was repealed by a newly elected government in June 2014 (Chan 2015). As such, Australia became the only developed nation at the time to act to reverse action on climate change (Chan 2015), and as one of the highest per capita emitting countries in the world due to its reliance on coal-burning power stations, faced a lot of criticism for this decision, with the World Bank citing Australia's repeal plans in 2014 as one of the biggest international threats to the implementation of similar programs elsewhere in the world (Taylor & Hoyle 2014).

The main motivation behind the repeal of the tax was to decrease the price of electricity and natural gas for households and industry (Chan 2015), arguing that the tax cost jobs and increased prices of goods and electricity, with no significant environmental benefits (Chan 2015). Some argue there were issues with the tax from the beginning, including poor planning, poor implementation, and lack of public support (Robson 2014). Due to weak political support for the tax, it lacked political robustness and credibility from the beginning, with no full cost-benefit analysis of the tax to support its implementation (Robson 2014; Jotzo 2012). This, along with mixed public and political opinion and strong opposition from manufacturers and businesses, is what led to the repeal of the tax 2 years later (Taylor & Hoyle 2014).

Despite these issues, others state many positive benefits of the tax during the 2 year period of implementation, including a decrease in total national GHG emissions by 8.2% compared to the two years prior to tax and AU$6.6 billion raised in tax in the first year, which was used to help compensate households for increased electricity prices and assist in funding of green programs (Chan 2015). The carbon tax also led to a decrease in electricity demand by 4% as compared to the 2 years prior to implementation, increased energy efficiency by encouraging more sustainable energy behavior in households (decline of 4.6% in the amount of CO_2 per MWhr electricity from 2012 to 2014), and allowed the economy to continue to grow with no direct evidence of affecting employment (Chan 2015). The tax did cause electricity prices to increase in homes (most offset by federal financial assistance) and in industry (15%) (Chan 2015).

After the election of a new Prime Minister in 2015, an Emissions Reduction Fund (ERF) is now being introduced as part of the government's Direct Action Plan (DAP), following the repeal of the carbon tax. Australia's original ETS plans in 2011 were a more traditional cap-and-trade scheme like the EU ETS, covering all KP GHGs, targeting specific sectors, and expressing interest in international linkage (Flachsland et al. 2008). In contrast, the ERF is not technically a trading scheme, but acts similarly by pricing carbon and creating a national market for credit units called Australian Carbon Credits Units (ACCUs) (Australian Government 2014). Under the DAP, the government has committed to a reduction in emissions of 5% below 2000 levels by 2020 and ERF will be the main mechanism to accomplish this (Australian Government 2014; Jotzo 2012). It will begin in July 2016, working alongside existing low carbon programs such as the Renewable Energy Target, energy efficiency standards and the Carbon Farming Initiative (CFI) (Australian Government 2014; Macintosh & Waugh 2012).

The ERF includes 3 elements: crediting, purchasing and safeguarding, and will allow for the use of existing credits, such as CDM, as long as they meet the requirements of the ERF. Under this system, facilities that exceed 100,000 tCO_{2e} are required to keep their emissions below the determined baseline by buying or selling credits from registered emissions reductions projects, including upgrading commercial buildings, improvement of energy efficiency of facilities, reforesting, upgrading vehicles, etc. (Australian Government 2014). These credits are to be auctioned off by the Clean Energy Regulator and credits will be issued only for genuine emissions reductions that are additional to normal business practices (Australian Government 2014). The safeguard mechanism will be a unique aspect of Australia's carbon market and refers to a penalty fee applicable to the largest companies in the system (that exceed 100 000 tCO_e per year) (with electricity and transport sectors being exceptions) if they increase emissions above the set baseline. This is meant to help avoid leakage, which commonly has produced issues in other carbon markets globally, and ensure that success of the ERF is not undermined by significant increases in emissions in another sector of the economy (Australian Government 2014, 2016; UNFCCC 2015). The MRV process is also an important aspect of this system and will follow the already established process of the CFI, which has been successfully operating since 2011 to allow landholders to generate offset credits on a project basis (Macintosh & Waugh 2012).

FORMING AN INTERNATIONAL CARBON MARKET

Benefits and Risks of Global Cooperation

The currently fragmented, inconsistent status of carbon markets around the world, with significantly varying prices of carbon between jurisdictions, can act as a deterrent to carbon market development in some countries that fear climate action will affect the international competitiveness of some economic sectors (Kossoy et al. 2015b). This fragmentation also allows for carbon leakage, in which case aggregate emissions can actually increase if emissions move to more emissions intensive areas, undermining any positive environmental intentions of carbon market development (Fell & Maniloff 2015). Domestic policies in one country can affect emissions in other regions through carbon leakage and international trade, and in the case of independent ETSs, global emissions abatement can vary significantly from national abatement (Liu & Wei 2014). These factors indicate the need for international cooperation.

There are many incentives for the development of an international carbon market, as 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 (Johannsdottir & McInerney 2016; Kossoy et al. 2015b; Ranson & Stavins 2016; Carbone et al. 2009; Haites 2016; Kill et al. 2010; Hawkins & Jegou 2014). There is also potential for global market linkage to foster sustainable development and minimize the development gap, as it could encourage low-carbon growth in poorer countries (Kossoy et al. 2015b). Many argue for these benefits as reasons that existing trading systems should become compatible and linkable, with similar methodology, tools, standards and indicators (Johannsdottir & McInerney 2016; Ranson & Stavins 2016; Carbone et al. 2009; Haites 2016; Kill et al. 2010).

An international trading scheme does run the risk of nonperformance or free-riding of certain countries, in which case strict regulations and MRV are crucial (Knudsen 2015). International markets are also harder to regulate and can create issues regarding distribution and loss of regional control (Hawkins & Jegou 2014; Haites 2016; Kill et al. 2010). Linkage would likewise require a great deal of compromise between policy makers in order to coordinate differences in ETS design (Hawkins & Jegou 2014) and there would be a necessary transition period for currently operating ETSs where compliance instrument prices would change for the firms involved (Haites 2016; Kill et al. 2010).

Transition to an international carbon market will require cooperation at all levels, but could provide benefits to all countries either by transferring resources to another country or by being a recipient of those transfers (Kossoy et al. 2015b). The primary goal of linkage is to achieve the same level of emissions reductions at a lower cost, but linkage is also a multi-faceted policy decision that can be used strategically to form international collaboration and mutual trust (Ranson & Stavins 2016). The current trend towards carbon market development and linkage suggests that the benefits do outweigh the risks for a lot of countries, and point to the emergence of a decentralized, bottom-up international system.

Carbon Markets of the Kyoto Protocol

The KP entered into force in 2005 and introduced three market-based mechanisms for GHG emissions reductions: International Emissions Trading (IET), CDM and JI (UNFCCC 2014, 2016). These mechanisms are still relevant and highly used, particularly for those countries that have entered into a second commitment period (2013-2020) under the KP (UNFCCC 2016a). Under IET, permits called Assigned Amount Units (AAUs) were allocated to industrialized countries with emissions targets and were meant to help these countries meet their KP targets by allowing them to trade AAUs (Kill et al. 2010; UNFCCC 2014). Unlike the EU ETS, where entities not covered by the cap can participate in trading, the IET allows only those countries with compliance targets and allocated permits to trade among themselves (Kill et al. 2010). Through IET, the KP created demand for carbon offsets and it also provided a mechanism to meet this demand using CDM and JI (Kill et al. 2010). Under these offset mechanisms, 3 additional units may be traded: a removal unit (RMU) for LULUCF activities such as reforestation; an emission reduction unit (ERU) generated by a JI project; or a certified emission reduction (CER) generated by a CDM project (UNFCCC 2014).

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, which presumably costs less than reducing emissions in their own country (Rahman & Kirkman 2015; Kill et al. 2010). This allows countries capped by their KP target to emit beyond their cap as long as they pay uncapped countries to reduce extra emissions. This mechanism is meant to help decrease emissions while stimulating sustainable development and providing industrialized countries with flexibility in meeting their reduction targets (UNFCCC 2016a). CERs, each equivalent to one tCO_2, can be earned by implementing an emissions reduction project in a developing country (such as a rural electrification project using solar panels) and can be used towards meeting KP targets (UNFCCC 2016a). The use of CERs is still popular as they are often priced much lower than carbon tax and domestic carbon allowances (Kossoy et al. 2015b). In 2009, the trade in carbon credits generated by CDM was worth around USD17.5 billion (Kill et al. 2010) and CDM is estimated to have the potential to issue about 6,600 $MtCO_{2e}$ between 2015 and 2020 (Kossoy et al. 2015b). The CDM has been a key policy in linking jurisdictions through offset projects by providing common offset standards to help facilitate coordination between carbon pricing mechanisms (Kossoy et al. 2015b; Haites 2016). With the recent signing of the Paris Agreement, the role of CDM beyond 2020 will be its integration into the NMM framework (Kossoy et al. 2015b; UNFCCC 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. As of March 2015, about 872 million ERUs had been issued under JI (Kollmuss et al. 2015).

Although these mechanisms provide flexibility for countries to meet their targets, and in the case of CDM, can act to stimulate sustainable development (Rahman & Kirkman 2015; UNFCCC 2016a), research has shown that these mechanisms have led to an increase in emissions above KP targets (Kollmuss et al. 2015). This is not due to the design of these mechanisms, but instead is due to poor regulation and MRV, as offsets reported from non-additional or over-credited projects have led to an increase in global emissions and threatened the environmental effectiveness of the system (Kollmuss et al. 2015). JI, for example, has been estimated to have led to about 600 million additional tCO_{2e} emissions than if emissions targets were met domestically (Kollmuss et al. 2015) since an estimated 75% of reported ERUs do not represent additional emissions reductions. Emissions reductions through CDM have also been highly criticized (Gavard et al. 2013). CERs are meant to be distributed for measurable and verifiable emissions reductions that are additional to what would have occurred without CDM, but the issue of over-reporting or over-crediting affects the reliability of these credits (Rahman & Kirkman 2015). This issue is a threat to the environmental integrity of systems in countries that plan to link internationally, as the incorporation of these credits into the EU ETS, for example, is estimated to be undermining the EU's reduction target by about 400 million tCO_{2e} (Kollmuss et al. 2015).

Aside from these issues with the regulation of its carbon trading mechanisms, some criticize the KP as a whole for having a failed design and limited effectiveness (Rosen 2015). Experts have pointed out that even full participation and compliance with KP would have failed to meet the environmental objectives of the agreement and would still represent under-management of climate change (Rosen 2015). Even though KP set a relatively low threshold for reductions, many countries struggled to comply and either dropped out (such as Canada) or did not meet their obligations (such as Japan), and others chose not to participate in the second commitment period (Rosen 2015). Three key features of KP that have been criticized are: too short of a commitment period (5 years) promoting shortsighted policies and not allowing for the necessary long-term economic and social changes to occur; requirement of small, binding emissions reductions that don't incentivize innovation and policy experimentation; and measurement of reductions using net emissions (rather than gross emissions) and assignment of carbon outputs to the producer as opposed to consumer of the products, discouraging true emissions cuts and encouraging carbon leakage (Rosen 2015). Due to the open-ended nature of the KP mechanisms, it is especially important to address these concerns in the future development of an international carbon market and linkage of domestic ETSs in order to ensure these flaws are not incorporated into a wider climate regime and that this environmentally ineffective structure is not perpetuated (Rosen 2015).

Future International Market Development

There exists an apparent preference for linking ETSs as a climate mitigation policy, with many of the world's cap-and-trade systems already linked, whether 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 (Ranson & Stavins 2016; Carbone et al. 2009). Politics are a particularly influential factor in carbon pricing, as illustrated by the subnational consensus that has arisen in the absence of national policies and has led to state or multi-state level carbon pricing approaches in many countries (Kossoy et al. 2015a). After reviewing the trends in carbon market development around the world, there are 4 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 bottom-up; indirect linkage of national and regional ETSs through common use of credits such as CDM; or a mixture between these approaches, containing elements from each (Flachsland et al. 2008; Rudolph & Kawakatsu 2012).

The current state of carbon markets and recently proposed INDCs suggest emergence of a decentralized bottom-up market design, as opposed to the indirect, top-down market previously attempted by the KP. Top-down global climate negotiations have progressed slowly and the emerging bottom-up mitigation efforts may be a more practical option to coordinate climate action (Liu & Wei 2014). Bottom-up initiatives have become very important in global climate policy (Rudolph & Kawakatsu 2012) and a growing network of decentralized, direct linkages may be key in the development of future global climate policy (Ranson & Stavins 2016), particularly for developing countries seeking flexibility in emissions caps. Many models of global carbon market development 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).

Three important elements that need to be considered when developing an international carbon market framework are: the ability to link carbon market systems together between countries and regions; transparent and consistent rules that account for the transfer of international emissions reductions; and tools and regulations that allow for links between different carbon-pricing systems (Johannsdottir & McInerney 2016). There are many factors to consider in order to address these pertinent issues and ensure consistency and compatibility, including how the emissions cap and price cap is set, MRV, penalties and compliance enforcement, banking, borrowing, allocation, regulating bodies, credits, sectoral coverage, and duration of trading and compliance periods (Flachsland et al. 2008).

Linking of systems is much simpler to implement if system designs are similar (or virtually identical), and therefore currently developing markets should consider this need for consistency in their design (Haites 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 (Pang et al. 2015). Cap setting and allowance allocation should be mutually recognizable between linked systems, and MRV standards and technical registry standards would be preferable identical, while coverage and scope don't necessarily need to be coordinated between systems (Pang et al. 2015).

Many lessons have been learned from previous attempts to develop a global market under the KP; 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 non-additional projects to be favoured (Kollmuss et al. 2015). Important aspects of a successful international market will require clear ambition of INDCs that have been converted into multi-year emission targets, as well as stringent and agreed upon international accounting rules (Kollmuss et al. 2015). Most importantly, in order to achieve environmental goals, a main requirement, which has not been followed to date, is that the price of carbon needs to be high enough and consistent enough to achieve the intended environmental benefits, not set at what the market can bear (Kill et al. 2010).

A NMM has been proposed by the Paris Agreement as a more holistic approach to an international carbon market (Gavard et al. 2013). One potential mechanism for this market 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. If this type of mechanism were adopted, limits would need to be placed on the amount 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). It is important to note that although a perfect limit on sectoral trading that reduces international emissions exists in theory, implementing that policy in practice would require close regulation and careful design to access the positive environmental and economic benefits and avoid a situation that leaves the environment and international market worse off than before. Another potential international market approach that was proposed prior to COP21 in December 2015 is cooperation through the formation of carbon market clubs, in which groups of countries agree to work together in exchange for exclusive membership benefits (Swartz 2016). This unique bottom-up approach to market design is a potential outcome of Article 6 of the Paris Agreement (Swartz 2016).

International Linkage: EU ETS

The EU ETS is a particularly valuable example when considering the development of an international trading scheme, as it demonstrates cooperation between 31 different countries, and more importantly, has demonstrated successful linkage of initially separate ETSs. Initially a separate carbon market system, the United Kingdom Emissions Trading Group (UK ETG) began in 2002 (Ellerman & Buchner 2007; Smith & Swierzbinski 2007) as a voluntary ETS including about 50 sectors and all 6 GHGs (Christiansen & Wettestad 2002). The UK scheme changed (by making compliance mandatory and adhering to the targets set by the EU) to accommodate entry into the second compliance period of the EU-wide scheme in 2007 (Christiansen & Wettestad 2002; Environmental Defense Fund (EDF) 2013).

A similar situation will likely occur for the Ukraine, another non-EU European country, which has a carbon market pilot phase scheduled for implementation from 2017-2020 and plans for eventual linkage with the EU ETS in 2019 (ICAP 2016). Although concrete plans are not yet in place, and the feasibility of this timeline has been questioned, the first 4-year phase is expected to cover large installations (>50MW) in the power, heat generation and industrial processing sectors, and the second phase will expand to include smaller installations (20-50MW) (ICAP 2016). The system will be designed to be compatible with the EU ETS, with 90% of allowances freely distributed in the pilot phase (the remaining 10% of allowances auctioned) following the EU ETS methodology for national allocation. The goal of this system is to reduce emissions by 20% below 1990 levels by 2020 (ICAP 2016).

The EC continues to actively pursue internationalization of its carbon market (Alexeeva & Anger 2015) and there has been a large amount of research done on the potential linkage between the EU ETS and other established or establishing ETSs around the world. Modelling by Alexeeva & Anger (2015) determined that the integration of the EU ETS with other ETSs yields an economic welfare gain for all participating regions, however the non-EU region may face competitiveness losses by linking. Modelling of potential future linkage of a national Chinese ETS with the EU ETS shows a joint ETS, in this case, could actually lead to an increase in emissions (Liu & Wei 2014). There are two main issues with linking a Chinese ETS to the EU or other international markets: China currently uses an intensity target as opposed to an absolute cap, and its system allows for ex-post adjustment of emissions allowances (Liu & Wei 2014; Pang & Duan 2015; Duan et al. 2014). The use of an intensity target allows for flexibility in the target to move with the GDP, ensuring that the carbon market doesn't hinder future economic development. This also means, however, that direct linkage of this type of ETS in China with the EU ETS would considerably reduce carbon prices in the EU and could threaten the effectiveness of the joint ETS (Liu & Wei 2014). This link would reduce the cost of mitigation in both regions, but the EU would achieve almost all emissions abatement abroad in China due to the low cost, and the total amount of emissions reductions would remain higher in both regions if left independent (Liu & Wei 2014; Gavard et al. 2013). This issue may present itself as a major barrier to an environmentally beneficial linkage between these two systems, unless policy design includes compatible policies in both regions, meaning an absolute cap on emissions in China. It is very possible that China will set a price floor and ceiling to ensure carbon pricing remains stable and lower than competitors, which could lead to carbon leakage and competitiveness concerns in other markets (Swartz 2016).

Another potential scenario that has been modelled is the linkage between the EU and South Korea, in which findings suggest that South Korea would likely benefit from linkage with the EU ETS due to its high carbon price. Linkage with the EU could reduce the cost of carbon in South Korea and in turn, reduce the risk of leakage or non-compliance, currently key issues among this system (Hawkins & Jegou 2014). Such a linkage would be facilitated by the similarities in design, MRV regulations and banking rules between these two systems (Hawkins & Jegou 2014). A challenge here, similarly to China, would be the overall allocation readjustment policy in South Korea's market, which would need to be clearly defined in order to facilitate effective collaboration (Hawkins & Jegou 2014).

The supply of carbon offset credits from developing countries is a major driver of allowance surpluses in the EU and is an important potential consequence of linkage that the EU must navigate carefully. The amount of tradable offset permits between regions has a significant effect on the EU carbon price, leading to a decrease in price in all potential linking scenarios (Gavard et al. 2013). However, it is possible in theory to find an optimal limit of the amount of tradeable permits that benefits both parties and the environment through linkage (Gavard et al. 2013)

ROLE OF FORESTRY IN CARBON MARKETS

Forests are recognized by the UNFCCC under the LULUCF sector as an important way of offsetting emissions and have an important role to play in climate policy and carbon markets due to their inherent ability to act as a carbon sink (Ruddell et al. 2006). The mitigation potential of forestry projects is estimated to be 1.5-3.5 $GtCO_{2e}$ per year (Olsson et al. 2016). Many countries have stated in their INDC that forestry or LULUCF will be included in their emissions reduction targets, but the forestry sector is currently used predominantly for offset projects through CDM instead of fully participating in ETSs. Between 2006 and 2015, 57 afforestation or reforestation projects were used to gain ERUs under CDM (UNFCCC 2016b). The majority of these projects have taken place in India to help restore degraded lands through reforestation, followed by Uganda, Kenya and China (UNFCCC 2016b). Many LULUCF projects are currently excluded from CDM due to the high degree of statistical uncertainty in measurements and in permanence of carbon sinks, with currently eligible projects limited to afforestation and reforestation (Olsson et al. 2016). It is important to remember that the current role of forestry as an offset mechanism under CDM is temporary, as offsetting cannot continue forever. Binding, ambitious, quantitative agreements between countries focusing on long-term transformation that includes forestry and other LULUCF activities will be the real solution (Olsson et al. 2016).

Despite its potential, there are challenges that come with including forestry (and other LULUCF activities) in carbon markets. These challenges include carbon calculating under the effects of non-permanence and the rebound effect, and the relationship between forestry projects and larger-scale national targets (Zald et al. 2016; Olsson et al. 2016). It is difficult to accurately calculate forest carbon due to large uncertainties in management, disturbances and fate of wood products, which strongly influence carbon sequestration and emissions in forests (Zald et al. 2016). The issue of permanence is unique to LULUCF projects and arises from potential threats to these sinks from natural disturbances or human intervention (Olsson et al. 2016). Another factor to consider in carbon calculating, although not as important in forestry as in other LULUCF sectors, is the rebound effect, where energy conservation in one area leads to energy use in another, therefore creating a loss in energy conservation. In the case of forestry, this could occur when wood is harvested for wood products and paper production that lead to new businesses and stimulate the use of these resources in the economy (Olsson et al. 2016). When including forestry in carbon markets, a reliable and complex forest carbon calculator that incorporates these effects and is coordinated across jurisdictions is an essential tool (Zald et al. 2016).

California and Forest Carbon

California's ETS currently allows domestic forestry projects (anywhere in the United States) to be used to gain offset credits, accounting for up to 8% of a regulated facility's required emissions reduction (Forest Carbon Partners 2016; Lueders et al. 2014). Eligible forest carbon offset projects must follow ARB's Compliance Offset Protocol for US Forest Projects and may include reforestation, improved forest management and avoiding conversion of timberland to non-forest use (ARB 2016; FCP 2016). Reforestation refers to the establishment of forests on land that has not supported trees over a relatively short period of time, as opposed to afforestation which is establishment of forest on land that has historically not contained forest (Freeman 2016). Improved forest management uses techniques designed to improve the productivity of land being used for silviculture such as increasing the overall age of the forest by increasing rotation ages or thinning diseased and suppressed trees, managing competing brush and maintaining stocks at a high level (Freeman 2016). 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 the future, ARB may allow offset credits for international forest programs through sector-based crediting (ARB 2016). California is currently considering the inclusion of REDD+ offset projects in the cap-and-trade program. However, it is both technically and politically difficult to implement REDD+ projects while maintaining the integrity of ARB's current offset project protocol (Lueders et al. 2014).

The projects allowed by ARB follow strict guidelines and rules regarding reference levels (BAU baseline must be modeling over a 100 year period and 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, maintain age class diversity, and maintain carbon in live trees), and monitoring and reporting (complete inventory of carbon stocks reported each year) (ARB 2016). These projects allow forest owners to manage their forests for both log sales and carbon offset sales (FCP 2016). A current example of a forest carbon offset project in California is Hanes Ranch, which is a mixed Redwood, Douglas-fir and hardwood family forest registered with the ARB that had issued over 85,000 offset credits in 2014 and projected to issue 140,000 credits by 2018 (FCP 2016).

China and Forest Carbon

China has a strong history of forest carbon trade, with many afforestation and reforestation projects in operation, most of which are registered with CDM (Forest Carbon Asia 2013). The first forest carbon project eligible for Chinese Certified Emission Reduction (CCER) credits in China is the Guangdong Changlong Carbon Sink Forestation Project, which has been verified by the National Development Reform Commission (NDRC) with carbon credits recently purchased by Yuedian Corporation, priced at a value of 20yuan/tonne, in June 2016 (Xiaodong 2016; Li 2016). The project began in January 2011 and operates at 4 sites including Xingning City, Zijin County, Dongyuan County and Wuhua County in China. It is an afforestation project and follows the carbon sink methodology developed by the NDRC. This methodology includes a detailed verification process including uniqueness, compliance, calibration frequency, rationality and rectification criteria (Xiaodong 2016). Since implementation, 13,000 mu of forests have been planted as part of this project, which is estimated to generate a sink equivalent to 34,000 tCO_2 over the next 20 years (Li 2016).

New Zealand and Forest Carbon

New Zealand is the only ETS to officially include the forestry sector in its ETS (Jiang et al. 2009) and allows carbon credits to be gained from forest sinks (Manley 2012). Forestry was the first sector to enter the New Zealand ETS on January 1, 2008, due to the importance of this sector in meeting New Zealand's emission targets (Ministry for the Environment 2016). Although forestry participates in the ETS, this sector is treated differently than other participating sectors, and is classified differently depending on whether the forest was established after 1989 or before 1990. Pre-1990 forest owners receive a one-off allocation of NZUs (60, 39, or 18 NZUs per hectare depending on when the pre-1990 land was acquired) to account for the decrease in land value due to decreased land-use flexibility under the ETS, and as such, face obligations under the scheme only if they deforest the land (New Zealand Government 2012; Ministry for the Environment 2016). As of 2013, these forest land owners can deforest their land without surrendering NZUSs if they establish an equivalent new forest on eligible land elsewhere (New Zealand Government 2012). Post-1989 forest owners can choose to enter the ETS and earn NZUs as the forest grows, but do not face any mandatory obligations and therefore do not receive NZU allocations (Ministry for the Environment 2016).

By including forestry in its carbon trade, there is potential for the carbon market to influence forestry practices by increasing forest profitability, influencing the choice of silviculture and increasing forest rotation length (Manley 2012). By including the forestry sector, New Zealand's ETS is expected to improve the profitability of afforestation in the country in the long-term by affecting land prices (Manley 2012). As carbon prices increase, regimes that produce more biomass may become preferred and log production less important, which could lead to positive changes in forestry practices that favour increased biomass (Manley 2012). Success of this system is questionable, however, as a 2015 survey conducted by the Ministry for Primary Industries found a 6% decrease in planting since 2013, and 30% decrease since 2012, as well as 99.5% of offset credits surrendered in New Zealand to be imported more cheaply from another country (mostly ERUs under the KP) (Metz & Tannenbaum 2015). The government also received a large increase of 18.4 million emissions units surrendered from 2012 to 2013, 94% of which were from the forestry sector, likely a result of increasing deforestation rates (Metz & Tannenbaum 2015). Deforestation occurring despite the incentive to maintain forests for carbon credits indicates that the cost of offset credits does not outweigh the economic benefits of deforestation, likely due to the availability of cheap international offset credits. In response to this, international offset units are not eligible for surrender under the NZ ETS as of June 1, 2015 (ICAP 2016).

New Zealand's forestry offset procedure is structured very differently than California's, leading to different types of offset projects. Carbon assessment is done through a combination of remote sensing techniques and measurement tables (yield tables and an area by age class table) (Beets et al. 2014). The New Zealand Ministry for the Environment developed the Land Use Carbon Analysis System (LUCAS) to create a national inventory of carbon stocks and help to assess forest carbon projects. A current forest offset project example in New Zealand is the Rarakau Forest Carbon Project, which was developed between 2009 and 2014 (Weaver 2016). It is New Zealand's first and only carbon offset project in a tall indigenous rainforest and provides offset credits through improved forest management (Weaver 2016). The forest is located in Tuatapere, Southland and is 738 ha, with an estimated total emissions reduction in 2015 of 14,715 tCO_{2e} (Weaver 2016). Original forest cover was predominantly beech (Nothofagus spp.) mixed with rimu (Dacrydium cupressinum), but portions have been logged and farmed, with some exotic tree planting in the past, and is now being reverted back to native forest (Weaver et al. 2012). This is an improvement management project which will achieve GHG emissions removal and reduction by terminating commercial logging and fire management activities that affect the process of natural succession (Weaver et al. 2012).

CONCLUSION

Successful implementation of climate policy instruments, whether cap-and-trade or 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). It is absolutely necessary to meet the 2^{o}C goal set by 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 in reach, the emissions reduction ambition of countries must increase substantially and the system that enforces these reductions must be fair and forceful (Knudson 2015). According to this review, carbon markets could be a promising way to facilitate cooperation and achieve this goal as long as it is regulated transparently, stringently, and with positive environmental intentions and integrity (Kossoy et al. 2015b).

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Appendix A: Summary of all current emissions trading schemes

NORTH AMERICA

	California ETS	**Quebec ETS**	**RGGI**
Status			
Date implemented	January 2012	January 2013	January 2009
Stage	Second compliance period (2015-2017)	Second compliance period (2015-2017)	Third compliance period (2015-2017)
Participation and Coverage			
Participating Jurisdictions	California	Quebec	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, Vermont

Regulated emissions	CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, NF_3, other fluorinated GHGs	CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, NF_3, other fluorinated GHGs	CO_2 only
Percent of emissions covered	459.28 $MtC0_2e$ (2013)85% (2016)	85% (2016)	20% (2016)
Regulated sectors	Large industrial facilities (cement, glass, hydrogen, iron and steel, lead, lime, nitric acid, petroleum and natural gas, pulp and paper), electricity generation and imports, suppliers of CO2, natural gas, RBOB, distillate fuel oil, liquid petroleum gas and liquefied natural gas. Large industrial facilities (including cement production, glass production, hydrogen production, iron and steel production, lead production, lime manufacturing, nitric acid production, petroleum and natural gas systems, petroleum refining, pulp and paper manufacturing, including	Electricity, industry, fuel distributors and importers, small and medium-sized businesses	Fossil fuel-powered electricity generators (does not include imports)

	cogeneration facilities co-owned/operated at any of these facilities), electricity generation, electricity imports, other stationary combustion, and CO2 suppliers		
Emissions threshold	>25,000 tCO2e per year	>25,000 tCO2e per year Lower for fuel distributors starting 2016	>25 MW
Design and Features			
Reduction goal	1990 levels by 20201990 levels by 2020	20% below 1990 levels by 2020	50% below 2005 levels by 2020
ETS Cap	2016: 382.4; 2017: 370.4 382.4 $MtCO_{2e}$ (2016) 2016: 382.4; 2017: 370.4	65.3 $MtCO_{2e}$ (2015)	91 $MtCO_2$ (2014)
Carbon price (USD in 2015)	13	10	6

Allocation method	- Benchmarking - Mixed (10% auctioned in first compliance period)	Mixed – free allocation diminishes 1-2% yearly, 100% auction for electricity and fuel distributors	Approximately 90% available for sale at auction, remainder up to states
Price cap at auction	None	None	8 (2016) Safety Valve Trigger Event if exceeds trigger price (price increases 2.5% each year) use Cost Containment Reserve to
Price floor at auction	USD 12.73 in 2016	CAD 12.08 in 2015	USD 2.10 in 2016
Trading period	3 years	3 years	3 years
Compliance period	3 years	3 years	3 years
Banking	Yes (with limit)	Yes (with limit)	Yes
Borrowing	No	No	No

Regulating authority	California Air Resources Board	Ministry of Sustainable Development, Environment, Wildlife and Parks, Office of Climate Change, Carbon Market Directorate	Responsible state authority
<u>Credits and Linking</u>			
Eligibility of CDM/JI	Yes	Yes	No (unless safety valve trigger event)
Offset limit	Up to 8% of compliance obligation	Up to 8% of compliance obligation	3.3% of compliance obligation; 10% in safety valve trigger event
Linkage Status	Bilaterally linked with Quebec Expressed interest in linking with RGGI, Australia and EU	Bilaterally linked with California	No current plans to link but have expressed interest

Sources: ICAP 2016; Dahan et al. 2015; Kossoy et al. 2015a; RGGI Inc. 201

EUROPE

	EU ETS	Swiss ETS
<u>Status</u>		
Date implemented	January 2005	January 2008
Stage	Third compliance period (2013-2020)	First mandatory phase (2013-2020
<u>Participation and Coverage</u>		
Participating Jurisdictions	All 27 EU member states plus Norway, Iceland and Lichtenstein	Switzerland
Regulated emissions	CO_2, N_2O, PFCs	Monitoring required for CO_2, NO_2, PFCs
Amount of emissions covered	45% (2016)	11% (2016)

Regulated sectors	Power stations, industry (including oil refineries, coke ovens, iron and steel plants and production of cement, glass, lime, bricks, ceramics, pulp, paper and board), aviation, CCS installations, production of petrochemicals, ammonia, non-ferrous and ferrous metals, gypsum, aluminum, nitric, adipic and glyoxylic acid	Industrial manufacturing, electricity and heating, and transport fuel
Emissions threshold	>20MW power stations, >10000 tCO_2/year commercial aviation, >1000 tCO_2/year non-commercial aviation 2,084 MtCO2e in 2013	>20MW thermal output and >25000 tCO_{2e}/year emissions
<u>Design and Features</u>		
Reduction goal	20% below 1990 levels by 2020	20% reduction from 1990 levels by 2020
ETS Cap	2084 $MtCO_{2e}$ (2013) for stationary sources (decrease 1.74% per year) 210$MtCO_{2e}$/year for aviation	5.63 $MtCO_{2e}$ (2013) to be reduced 1.74% annually
Carbon price (USD in 2015)	8	9
Allocation method	Mixed – free allocation based on benchmarking, about 40% of allowances auctioned with different	- Benchmarking

	allocation rules for electricity, manufacturing and aviation.	- Mixed - 80% free allocation in 2013
Price cap at auction	No	No
Price floor at auction	No	No
Trading period	8 years (phase 3)	8 years
Compliance period	16 months	1 year
Banking	Yes	Yes with limit
Borrowing	No	No?
Regulating authority	European Commission and responsible state authorities	Federal Office of the Environment
Credits and Linking		
Eligibility of CDM/JI	Yes	Yes

Offset limit	50% of compliance obligations	11% of 5 times the average emissions allowances allocated in the voluntary phase (2008-2012) minus offset credits used during that time period
Linkage Status	Completed agreement to link with Swiss ETS	Completed agreement to link with EU ETS

Sources: ICAP 2016; Sopher & Mansell 2013; Kossoy et al. 2015a

CHINA

	Shenzhen pilot ETS	Shanghai pilot ETS	Beijing pilot ETS	Guangdong pilot ETS	Tianjin pilot ETS	Hubei pilot ETS	Chongqing pilot ETS
Status							
Date implemented	June 2013	November 2013	November 2013	December 2013	December 2013	April 2014	June 2014
Stage	Second compliance period ended June 2015	Second compliance period ended June 2015	Second compliance period ended June 2015	Second compliance period ended July 2015	Second compliance period ended July 2015	Second compliance period	Second compliance period
Participation and Coverage							
Participating	Shenzhen	Shanghai	Beijing	Guangdong	Tianjin	Hubei	Chongqing

Jurisdictions							
Regulated emissions	CO_2 only	CO_2 only	CO_2 only	CO_2 only	CO_2 only	CO_2 only	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6
Amount of emissions covered	40% (2016)	57% (2016)	40% (2016)	55% (2016)	60% (2016)	35% (2016)	40% (2016)
Regulated sectors	Power, water supply, manufacturing sectors, buildings	Airports, aviation, chemical fiber, chemicals, commercial, electricity, financial, hotels, iron and steel, petrochemical	Electricity providers, heating sector, cement, petrochemicals, other industrial enterprises, manufacturer	Energy, iron and steel, cement, petrochemicals. Ceramics, textiles, nonferrous metals, chemicals, pulp and	Heat and electricity production, iron and steel, petrochemicals, chemicals, exploration of oil and gas	Power and heat supply, iron and steel, chemicals, petrochemicals, cement, automobile manufacturing, ferrous metals, glass, pulp	Power, electrolytic aluminum, ferroalloys, calcium carbide, cement, caustic soda, and iron and steel

		s, ports, non-ferrous metals, building materials, paper, railway stations, rubber, textiles, paper, rubber	s and service sector	paper, construction		and paper, food and beverage	
Emissions threshold	3000 tCO_{2e}/year 20000m^2 public building 10000m^2 government buildings	20,000 tCO_2 (industrial) 10,000 tCO_2 (non-industrial)	5000 tCO_2/year	20,000 tCO_2/year or 10,000 tce/year	20,000 tCO_2/year	60,000 tce/year	20,000 tCO_{2e}/year
<u>Design and Features</u>							

Reduction goal	21% reduction in 2010 carbon intensity by 2015	19% reduction in 2010 carbon intensity by 2015	18% reduction in 2010 carbon intensity by 2015	19.5% reduction in 2010 carbon intensity by 2015	19% reduction in 2010 carbon intensity by 2015	17% reduction in 2010 carbon intensity by 2015	17% reduction in 2010 carbon intensity by 2015
ETS Cap	33 $MtCO_2$ (2015)	160 $MtCO_2$ (2015)	50 $MtCO_2$ (2015)	408 $MtCO_2$ (2015)	160 $MtCO_2$ (2015)	281 $MtCO_{2e}$ (2015)	106 $MtCO_{2e}$ (2015)
Carbon price (USD in 2015)	7	5	8	5	4	4	4
Allocation method	- Sector-specific benchmarking - Mostly free (up to	- Benchmarking for certain sectors - Free allocation	- Free allocation through grandfathering - Benchmarkin	- Grandfathering - Mixed (10% auctioned in 2015)	- Free allocation through grandfathering - Benchmarkin	- Free allocation through grandfathering - Small percentage auctioned	- Free allocation through grandfathering

<table>
<tr><td></td><td>3% auctioned)
- Ex-post adjustment is possible</td><td>- Ex-post allocation adjustment
- Some auction?</td><td>g for new entities</td><td></td><td>g for new entrants</td><td>(60% free allocation, 32% to new entrance reserve, 8% to government reserve of which 30% are auctioned)
- Ex-post adjustment is possible</td><td>- Ex-post adjustment is possible</td></tr>
<tr><td>Price cap at auction</td><td rowspan="2">No – DRC can sell extra from a reserve or buy back allowances to stabilize price</td><td rowspan="2">No – Environment and Energy Exchange can suspend trading or impose holding limits to stabilize prices</td><td rowspan="2">No – DRC can buy or auction extra allowances to stabilize price</td><td>No</td><td rowspan="2">No – DRC can buy or sell extra allowances to stabilize the price</td><td rowspan="2">No –DRC can buy or sell extra allowances to stabilize the price</td><td rowspan="2">No – In case of market fluctuation, compliance entities can’t sell more than 50% of their free allocation</td></tr>
<tr><td>Price floor at auction</td><td>CNY $40/tCO$_2$</td></tr>
</table>

Trading period	3 years	3 years	3 years	3 years	3 years	3 years	3 years
Compliance period	1 year	1 year	1 year	1 year	1 year	1 year	1 year
Banking	Yes	Yes	Yes	Only pilot phase	Only pilot phase	Only pilot phase	Only pilot phase
Borrowing	No	No	No	No	No	No	No
Regulating authority	Shenzhen Development and Reform Commission (DRC)	Shanghai Development and Reform Commission	Beijing Development and Reform Commission	Guangdong Development and Reform Commission	Tianjin Development and Reform Commission	Hubei Development and Reform Commission	Chongqing Development and Reform Commission
Credits and Linking							
Eligibility of CDM/JI	No	No	No	No	No	No	No

Offset limit	10% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects	5% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects	5% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects, 50% must come from projects within Beijing	10% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects, 70% must come from projects within Guangdong	10% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects	10% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects, credits must come from the province of Hubei or provinces that have signed agreements with Hubei	8% of annual compliance obligation using China Certified Emissions Reduction credits from domestic offset projects
Linkage Status	These 7 pilot ETSs are to be replaced with a national ETS in 2017. China has expressed interest in international linkage of this national system, particularly with the EU ETS.						

Sources: ICAP 2016; Xiong et al. 2016; Kossoy et al. 2015a

ASIA & OCEANIA

	NZ ETS	Tokyo ETS	Saitama ETS	South Korea ETS
Status				
Date implemented	January 2008	April 2010	April 2011	January 2015
Stage	First mandatory phase	Second compliance	Second compliance	First phase (2015-2017)

		period (2015-2019)	period (2015-2019)	
<u>Participation and Coverage</u>				
Participating Jurisdictions	New Zealand	Tokyo Metropolitan Area	Saitama Metropolitan Area	Republic of Korea
Regulated emissions	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	CO_2 only	CO_2 only	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6
Amount of emissions covered	52% (2016)	20% (2016)	18% (2016)	67.7% (2016)
Regulated sectors	Forestry, liquid fossil fuels, stationary energy, industrial processes,	Commercial and industrial	Commercial and industrial	Steel, cement, petrochemicals, refinery, power, buildings, waste and aviation

	agriculture, waste			
Emissions threshold	None?	>1500 kL of crude oil equivalents/year	>1500 kL of crude oil equivalents/year	Companies with >125000 tCO_{2e}/year, facilities with >25000 tCO_{2e}/year
<u>Design and Features</u>				
Reduction goal	5% reduction from 1990 levels by 2020	25% below 2000 levels by 2020	21% below 2005 levels by 2020	22% below 2012 levels by 2030
ETS Cap	None	10.44 $MtCO_{2e}$ (2020)	NA	562 $MtCO_{2e}$ (2016)
Carbon price (USD in 2015)	5	38	NA	9

Allocation method	- Mixed – intensity based allocation in the industrial sector with 90% free allocation to highly emissions-intensive activities and 60% to moderately emissions-intensive activities - Free allocation for forestry	- Free allocation through grandfathering	- Free allocation through grandfathering	- Free allocation through grandfathering
Price cap at auction	No, but fixed price option (NZD 25) acts	No – carbon price not controlled unless excessive	No – carbon price not controlled unless excessive	No – Allocation Committee may allocate

	as price ceiling	fluctuation occurs and the available credit supply for trading can be increased	fluctuation occurs and the available credit supply for trading can be increased	additional allowances from reserve, establish an allowance retention limit, increase or decrease borrowing limit or offset limit, or set up a temporary price floor/ceiling to stabilize market
Price floor at auction	No			
Trading period	1 year for most sectors	6 years	6 years	3 years
Compliance period	1 year for most sectors	5 years	5 years	1 year
Banking	Yes (unlimited), but not for fixed price units	Yes between consecutive periods	Yes between consecutive periods	Unlimited

Borrowing	No	No	No	Yes within single trading phase
Regulating authority	Ministry for the Environment	TMG Bureau of Environment	Saitama Prefectural Government	Ministry of Environment
<u>Credits and Linking</u>				
Eligibility of CDM/JI	Not as of June 2015	Yes	Yes	Yes, domestic only
Offset limit	None	None	None	Up to 10% of compliance obligation using domestic project credits only
Linkage Status	None	Unilaterally linked with Saitama	Unilaterally linked with Tokyo	Expressed interest in linking with Australia and Europe

Sources: ICAP 2016; Kossoy et al. 2015a