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University of Maryland
School of Public Policy
Center for Global Sustainability

IETA
A is for Ambition

Modelling the Economics of Article 6

A CAPSTONE REPORT

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Article 6 sets as one of its goals “holding the increase in global average temperature to well below 2°C."

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Summary

Article 6 is an important part of the Paris Agreement of 2015, which sets as one of its goals "holding the increase in global average temperature to well below 2°C above pre-industrial levels and [to pursue] efforts to limit the temperature increase to 1.5°C above pre-industrial levels." These goals imply that the Earth's carbon dioxide (CO_2) emissions must decline to net zero or below by mid-century or shortly thereafter. The primary mechanism adopted to control emissions is each country's Nationally Determined Contribution (NDC). The NDCs articulate near-term national goals to limit and reduce emissions. These goals are intended to become increasingly ambitious over time. Article 6 was included in the Paris Agreement to assist nations to achieve their NDCs more efficiently and to enable increased ambition. In this capstone, we use ambition to indicate the degree of emissions mitigation embodied in parties' NDCs.

"Article 6 was included in the Paris Agreement to assist nations to achieve their NDCs more efficiently and to enable increased ambition."

Research over the past four years has increased understanding and quantified the role Article 6 could play in facilitating the achievement of Paris goals. Important results flowed from this work, including:

In the near-term, cooperative implementation of NDCs using Article 6 could substantially reduce resources needed to achieve emissions reductions compared to achieving the same global outcome with all parties implementing their NDCs independently.

If the savings from cooperative implementation of NDCs using Article 6 were reinvested in increased ambition, emissions mitigation could be more than doubled.

Creating an "ambition club" whose members pledged to increase ambition proportional to use of Article 6 emissions trades could help increase ambition over time.

If Article 6 is implemented in accordance with the letter and spirit of the Paris Agreement, the "low-hanging-fruit" (LHF) problem does not emerge. The LHF problem was an issue dating back to the Kyoto Protocol. The concern was that if parties with no emissions obligation undertook low-cost near-term emissions mitigation, they might later find themselves without such opportunities under a future emissions limit. The Paris Agreement is structured such that all parties have self-imposed goals from the beginning of the agreement. Emissions mitigation beyond an NDC, i.e. the higher-hanging fruit, are paid for by the buyers.

If buyers of emissions mitigation can only use a fraction of Internationally Transferred Mitigation Outcomes (ITMOs) purchases toward meeting their NDC, we find that the cost of achieving parties' NDCs rises. In this case, ITMO buyers do more domestic emissions mitigation, but ITMO sellers reduce their total emissions mitigation. The result is higher cost with no climate benefit.

Toward 2050, the role of Article 6 shifts to allowing parties to cooperatively achieve net zero emissions with removals. Countries with the ability to deliver negative emissions (or removals) can sell to parties with greatest difficulty in achieving zero emissions. Physical transactions in the market over this period shrink, but each ITMO is worth more. The overall value of transactions remains comparable to near-term levels.

Countries that employ Article 6 mechanisms to cooperatively meet their NDC goals always benefit, whether they are a buyer or a seller. Not every country need participate in cooperative mitigation for those engaged in cooperation to benefit.

If countries arrange plurilateral cooperative approaches (or "clubs"), the degree of benefit and the role (buyer/seller) depends on the club in which a party cooperates. Early club membership means that benefits arise earlier. Membership in a club with a wider range of marginal costs increases the potential benefits to be obtained.

Introduction

Article 6 was established under the Paris Agreement of 2015 (United Nations, 2015) as a tool to help facilitate the Paris Agreement's goals, which include holding "the increase in global average temperature to well below 2°C above pre-industrial levels and [to pursue] efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (United Nations, 2015). These goals imply that the Earth's carbon dioxide (CO_2) emissions must decline to zero or below by mid-century or shortly thereafter and remain at zero thereafter. The primary mechanism for achieving the Paris climate change limitation goal is the Nationally Determined Contribution (NDC) reflecting near-term (initially through 2025 or 2030) intentions to reduce national emissions (UNFCCC, 2015).

Article 6 allows countries to engage cooperatively to achieve their NDCs either directly or through markets. Article 6 enables cooperating parties to have greater ambition while diverting fewer resources than would have been required had the parties acted independently. Article 6 created two primary pathways for cooperation embodied in Articles 6.2 and 6.4. Article 6.2 allows countries to set up bilateral or plurilateral arrangements for trading of emissions reductions or removals, referred to as Internationally Transferred Mitigation Outcomes (ITMOs). Article 6.4 creates a generic carbon market, similar in character to the Clean Development Mechanism under the Kyoto Protocol, in which projects can be registered to create ITMOs under the supervision of the UNFCCC. The goal of Article 6 is to enable parties to do more than they would have been able to do had they implemented their NDCs independently. It is a crucial principle of Article 6 that emissions mitigations are real, and that double counting is avoided.

Over the course of the past four years, we have conducted scientific research to better understand the potential role Article 6 activities might play in achieving overall Paris goals. In this report, we summarize and highlight some of the more salient findings of that body of research.

Much of the work employed the Global Change Analysis Model (GCAM). Figure 1 (Panel a) lists the 32 geopolitical regions in GCAM. GCAM represents energy, economy, agriculture, land-use, water and climate in a coupled modeling system to ensure consistency across human activities. We provide more detail on the GCAM model in an Appendix to this paper along with instructions on how to access a full model documentation, a copy of the model, its underlying databases, and instructions for users, for those interested.

"Article 6 allows countries to engage cooperatively to achieve their NDCs either directly or through markets. Article 6 enables cooperating parties to have greater ambition while diverting fewer resources than would have been required had the parties acted independently."

Article 6 in the Near-Term

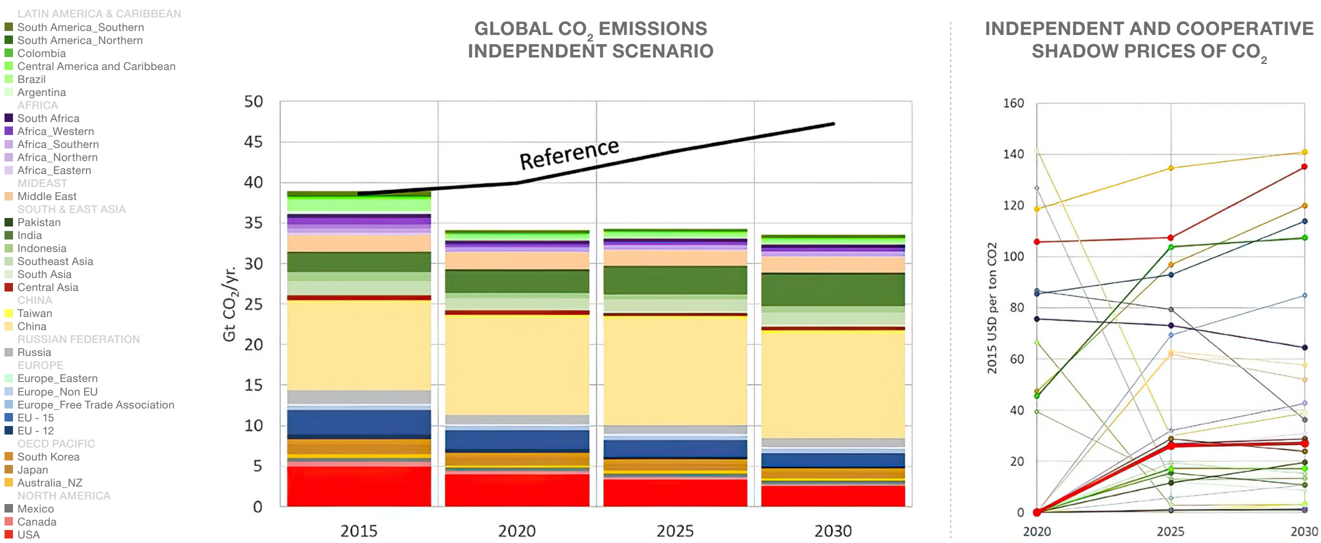
In the near-term, cooperative implementation of NDCs using Article 6 could substantially reduce resources needed to achieved emissions reductions compared to achieving the same global outcome with all parties implementing their NDCs independently.

Our research (Edmonds, et al., 2021) confirms a classic economic principle, that whenever the marginal cost of producing an outcome differs across countries, opportunities exist for cooperation to achieve the same outcome with net gains for all parties. We note all of the NDCs proposed by all parties and convert them into quantified emissions limitations. We allow countries for which emissions reductions opportunities are greater than those required to meet NDC to transform them into internationally transferred mitigation outcomes (ITMOs). These can be sold to countries for which emissions reductions opportunities are more difficult or expensive for meeting their NDC. Note that we also apply a corresponding adjustment (CA) to the selling party's emissions mitigation. This ensures that double-counting does not occur, and that global emissions mitigation is identical regardless of whether countries implement NDCs independently or cooperatively.

Figure 1 Panel b shows a global emissions forecast with current policies (Reference) and a scenario that assumes that all parties achieve their unconditional NDC pledges (stack chart). Emissions are disaggregated into the 32 GCAM geopolitical regions shown in Figure 1 Panel (a), with colors differentiated by regions[1]. The marginal cost of independently achieving NDC goals for each is shown in Figure 1 Panel (c). The wide range of marginal costs across the Paris parties reflects both local circumstances and the stringency of their NDCs. The marginal cost of cooperatively implementing NDCs is shown as the solid "red" line in Figure 1 Panel (c). Parties with marginal costs that are below the cooperative price stand to gain from increasing emissions mitigation, creating ITMOs, and selling them to parties whose marginal costs are greater than the cooperative price. Conversely, parties with marginal costs above the cooperative price stand to gain by reaching their targets more cost effectively by buying ITMOs to achieve compliance.

1. The same color scheme is employed to represent trade volumes and carbon prices for different regions throughout the report

Figure 1. NDC Implications for global Emissions and marginal costs to independently implement NDCs



Changes in emissions mitigation activities around the world when NDCs are cooperatively implemented compared to independently implemented are shown in Figure 2. Figure 2 Panel (a) shows the financial transactions in a global Article 6 carbon market in which all NDCs are implemented cooperatively. Negative values indicate purchases of ITMOs, and positive values indicate sales of ITMOs. By 2030, the carbon market transactions surpass $100 billion/year (2015 USD).

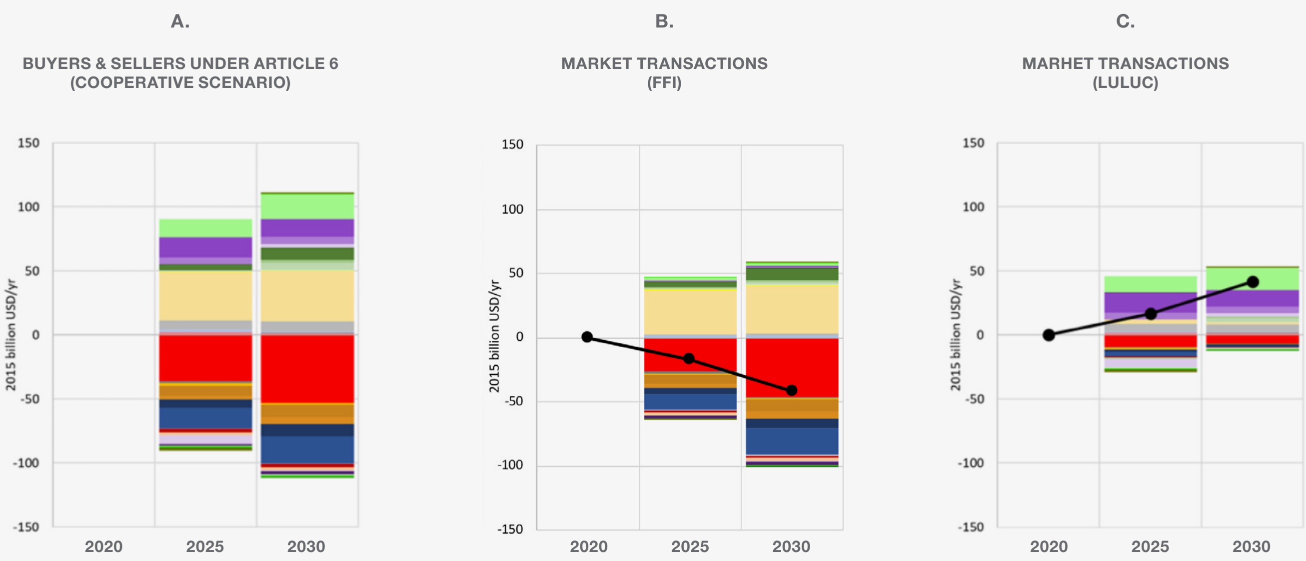
Corresponding to the financial flows are physical CO_2 emissions mitigation (ITMO) flows. We have disaggregated ITMO trading by primary activity: fossil fuel and industrial emissions reductions, and net increase in national carbon stocks, both relative to the reference scenario, Figure 2 Panels (b) and (c) respectively. We do not allow any ITMO to be created for actions that increase the stock of carbon relative to the reference scenario. Only actions that decrease the net carbon content in a region relative to the reference scenario can be transformed into ITMOs.

Sales of ITMOs generated by reductions in fossil fuel and industrial emissions are roughly equivalent to the volume of ITMOs arising from increased carbon stored in the agriculture-land-use sector in 2030. However, buyers apply ITMOs primarily to offset fossil fuel and industrial emissions (Figure 2, Panels b and c).

The cost of implementing NDCs independently and cooperatively are shown in Figure 3 Panels (a) and (b) respectively. The savings that accrue to each region from cooperative rather than independent implementation of NDCs is shown in Figure 3 Panel (c) All regions obtain some savings in cost.

"Changes in emissions mitigation activities around the world when NDCs are cooperatively implemented compared to independently implemented"

Figure 2. Cooperative implementation of NDCs financial and physical transactions



If the savings from cooperative implementation of NDCs using Article 6 were reinvested in increased ambition, emissions mitigation could be more than doubled.

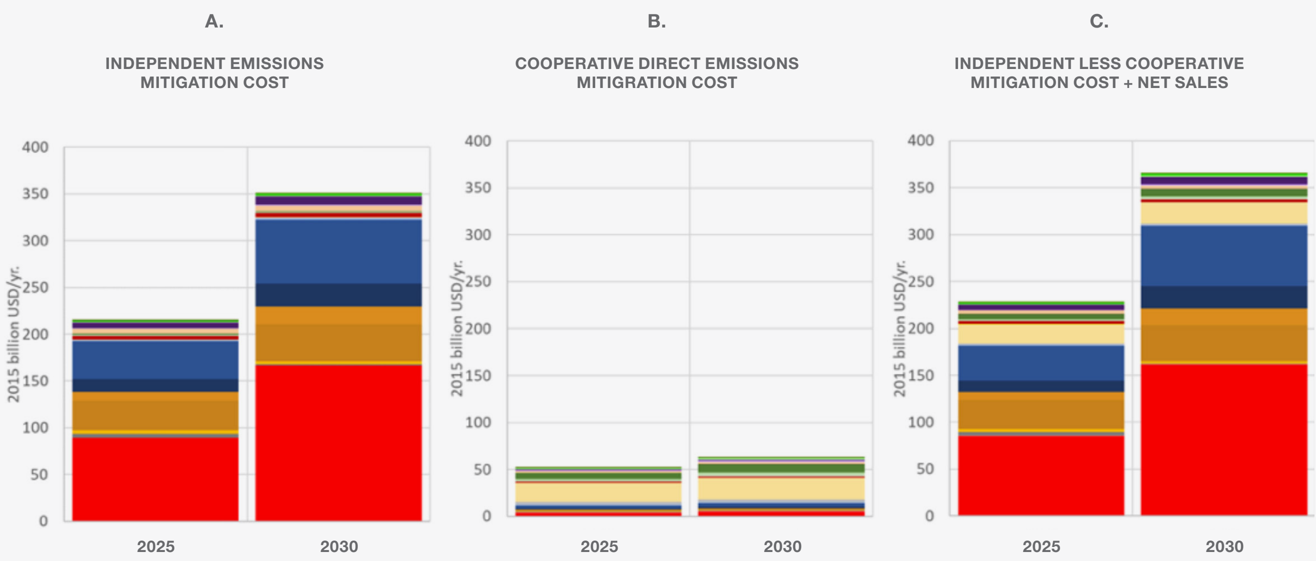
Figure 3 Panel (c) shows the savings available to cooperative implementation of NDCs relative to independent NDCs. If those savings were reinvested in increased ambition, emissions mitigation could be enhanced. The result of that calculation is shown in Figure 4. Figure 4 Panel (a) shows global emissions without NDCs (Reference, blue), global emissions assuming that NDCs are implemented (Independent, Cooperative, orange), and emissions if all parties reinvested their savings from cooperative implementation of NDCs back into enhanced ambition (Enhanced Ambition, green).

We also calculated region by region increases in ambition that could be facilitated by reinvesting the savings from cooperative implementation were reinvested in enhanced ambition, Figure 4 Panel (b). Every region could increase ambition without incurring any greater cost than would have been incurred with independent implementation of their current NDC.

Adding increased ambition as a condition of ITMO trading could help reduce emissions further over time.

One critique of Article 6 is that it provides an incentive for countries to maintain low ambition. That is, it acts as an incentive to maintain the emissions mitigation embodied in NDCs at low levels rather than to increase the stringency of emissions mitigation goals. Some argue that low-ambition countries with low abatement costs could sell ITMOs into the market and their emissions mitigation costs are more than covered by the proceeds from the buyer regions. A country with low ambition is thus being paid for all of its emissions mitigation efforts by outside parties. There is a disincentive to increase ambition toward the challenging goal of net zero CO_2 emissions by mid-century. Similarly, low ambition countries with high abatement costs could buy cheaper ITMOs from other countries to meet their targets instead of investing in ambitious domestic mitigation. We have not found evidence of such scenarios occurring in the real world, but they remain theoretically possible.

Figure 3. Costs of implementing NDCs independently and cooperatively



To address this issue, we explored a mechanism that used Article 6 to enhance ambition over time. One such mechanism was what we called an "Ambition Club". Members of the Ambition Club would be parties to the Paris Agreement who agree to exclusively engage in emissions trading with each other. A rule of the club would be a commitment to enhance ambition over time at least proportional to use of Article 6 trading mechanisms, that is, their ITMO transactions.

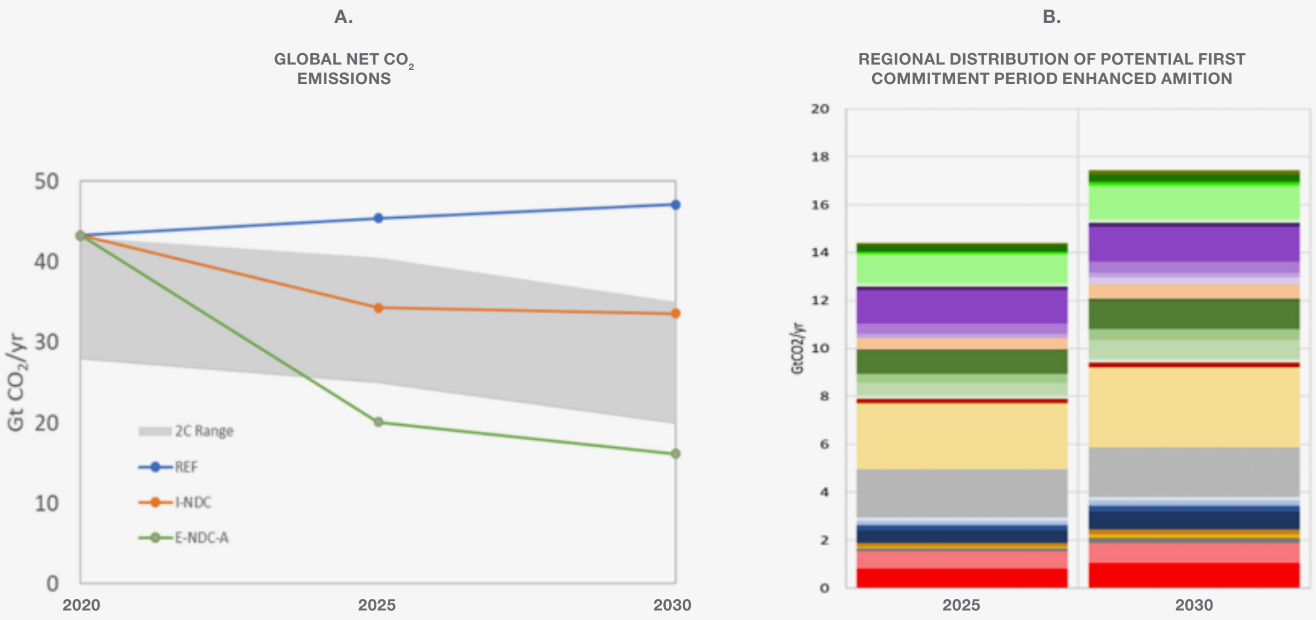
We created a "ratchet" mechanism as a rule for the hypothetical club. Each member of the club would agree to increase its NDC ambition by a percentage of the volume of ITMO purchases or sales. We explored three cases. In each case club members agreed to increase their next period ambition by a fraction of their ITMO trades: 12.5%, 25%, and 50%. Each of these ambition ratchets accelerated emissions mitigation, shows global emissions associated with each of the ratchet values, Figure 6. Ambition increases and global emissions decline as the ratchet commitment increases.

If Article 6 is implemented in accordance with the letter and spirit of the Paris Agreement, the "low-hanging-fruit" (LHF) problem does not emerge.

The LHF problem, sometimes also referred to as the "risk of overselling", was originally raised as a concern by developing countries about participation in the Clean Development Mechanism under the Kyoto Protocol. The basic idea was that if countries engaged in emissions mitigation and sold those reductions as offsets to parties with emissions limitation obligations, that the seller country would not have access to those emissions reductions opportunities later when they also had emissions limitation obligations.

"Each member of the club would agree to increase its NDC ambition by a percentage of the volume of ITMO purchases or sales."

Figure 4. Enhanced ambition: global and by region



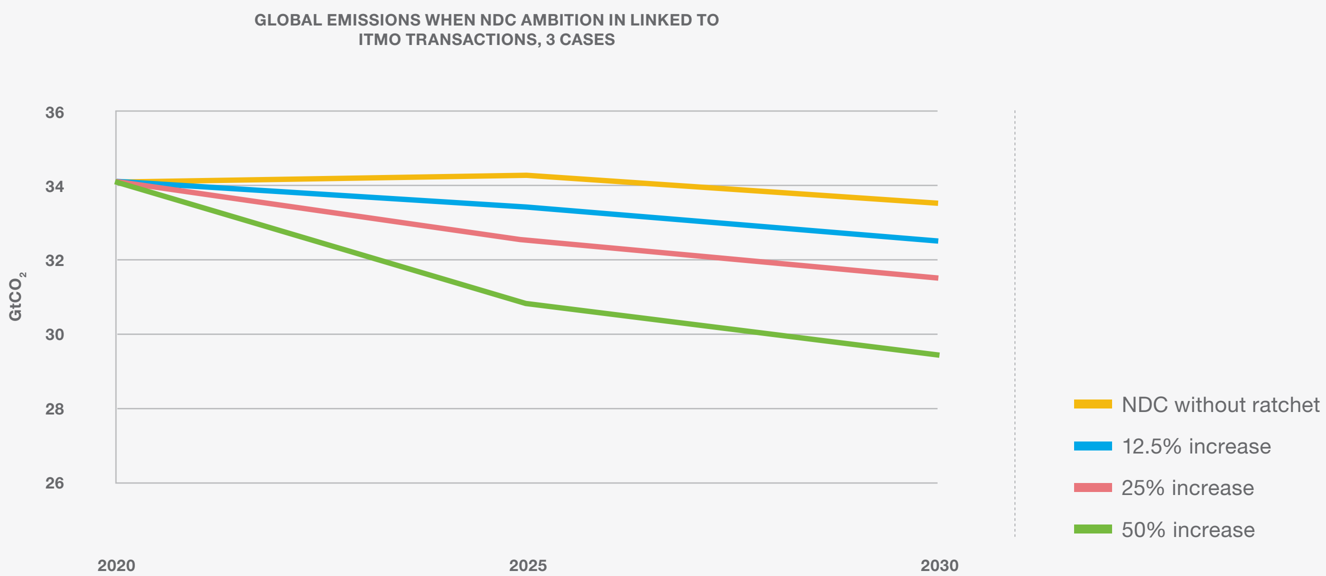
"the sales of ITMOs in one period can provide sellers with resources to put them in a comfortable position to increase ambition in the next commitment period."

The Paris Agreement is fundamentally different from the Kyoto Protocol, in that all parties have established NDCs. Our research shows that most developing countries have mitigation potential for meeting their NDCs with ample room to sell extra mitigation as ITMOs. Our modeling suggests that host countries can harvest the lowest hanging fruit to meet their NDCs, and then they create ITMOs for extra mitigation available below the clearing price on the international market. Furthermore, as discussed in our first two key findings, ITMO buyers provide financial resources and technology to sellers who would otherwise lack the ability to harvest all of their "low hanging fruit" (i.e. mitigation below the world clearing price). The seller countries' mitigation potential is more than adequate to build the underlying emissions mitigation capacity for both their NDC and ITMO sales. Importantly, the sales of ITMOs in one period can provide sellers with resources to put them in a comfortable position to increase ambition in the next commitment period.

A second check on the LHF problem is the crediting rules in the Article 6.4 mechanism and similar systems expected under the 6.2 cooperative approaches. The lowest hanging fruit is unlikely to meet financial additionality determinations, because the economics of the associated activities are so attractive that a country should be undertaking them without the use of financing from international carbon markets.

A related problem that appears within the Paris Agreement structure is whether it creates a perverse incentive to submit NDCs that are perpetually weak so as to put a country in a seller position. However, the Paris Agreement's NDC structure encourages countries to take progressively stronger targets and buyers are unlikely to be willing to trade with countries that without credible mitigation goals which do not abide to the spirit of the Paris Agreement. In addition, the additionality determinations in the implementation of the Article 6.4 mechanism or the trading standards or linkages recognized through Article 6.2 should be updated regularly to reflect baseline improvements in host countries.

Figure 5. Three cases in which next period NDCs are enhanced by a fraction of ITMO transactions. For example, in the 25% case, next period ambition was increased by one quarter of total ITMO transactions, accelerating global emissions reductions.

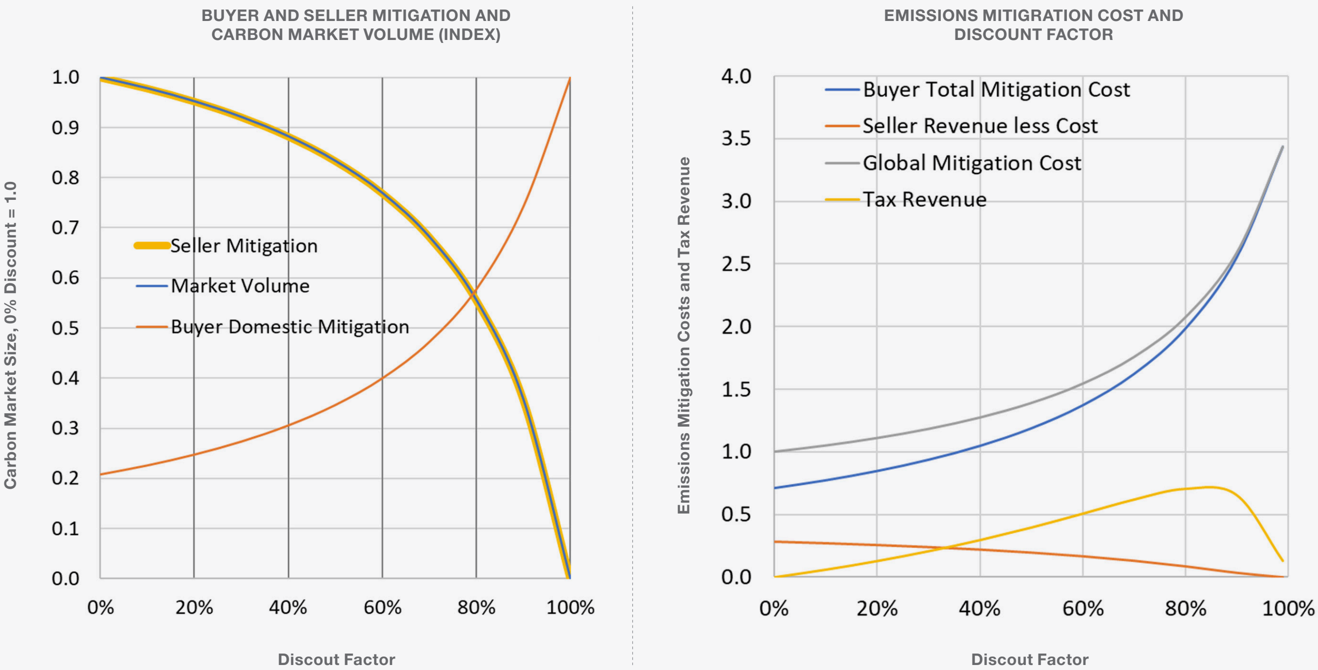


If buyers of emissions mitigation can only use a fraction of ITMO purchases toward meeting their NDC, we find that the cost of achieving NDCs rises, ITMO buyers do more domestic emissions mitigation, and ITMO sellers reduce their total emissions mitigation.

Discounting emissions mitigation transactions refers to a practice in which a share of the proceeds (SOP) from ITMO transactions are set aside and used for other purposes or cancelled to ensure overall mitigation in global emissions (OMGE). Such discounting is mandatory for transactions in credits issued by the new Article 6.4 Mechanism and encouraged for other transactions under Article 6 cooperative approaches. The buyer of ITMOs can apply only a fraction of the emissions mitigation toward implementing NDC goals. On the assumption that ITMOs must represent realized emissions mitigation, the application of a discount factor or SOP does several things: it generates revenue to the discounting institution, it increases domestic emissions mitigation in buying regions; it decreases emissions mitigation in seller regions, it increases the overall cost of mitigation, and in addition, it decreases the incentive to increase ambition.

To illustrate these features, we created a simple two-party model with one buyer and one seller in an ITMO market. In our simple illustration, Figure 6, cost values are normalized to one for the case in which carbon markets operate without transaction discounting. As the fraction of transactions that are discounted rises, the size of the carbon market shrinks, Figure 6 Panel (a). The burden of emissions mitigation is pushed back toward the buyers. Sellers reduce their emissions mitigation correspondingly. Consequently, the total cost of meeting the two parties' NDCs increases, Figure 6 Panel (b). Revenues collected by the implementing institution increase as the discount factor increases, up to a point. Eventually, further increases in the discount factor becomes counterproductive. In the longer term, higher mitigation costs arising from less efficient markets creates a disincentive to increasing ambition over time.

Figure 6. Impact of carbon market discounting on costs and revenue raised



Article 6 in the Long-Term

In the long-term, when NDCs are all at or near zero, the role of Article 6 shifts to enabling parties with the greatest difficulties in achieving zero emissions to cooperate with parties that can deliver negative emissions and thereby facilitating achievement of a long-term Paris goal. While the volume of physical transactions under Article 6 declines to low levels in this period, the value of transactions remains comparable to near-term levels.

We examined several scenarios that hold the average global temperature increase to between 1.6-2°C. We assume that nations increase their ambition such that global climate forcing is limited in the year 2100. This requires countries in aggregate to reduce emissions of CO_2 to close to zero or below.

We first examined 2°Cscenarios. Our assumed emissions pathways for national ambition are shown in Figure 7 Panel (a). Initially we assume that all countries implement their NDCs independently (I-NDC). The corresponding show prices associated with independent NDC implementation are shown in Figure 7 Panel (b). Because in all regions CO_2 emissions are falling to net zero, the wide disparity of marginal costs that exists in the first commitment period is reduced, but not eliminated. Marginal costs, or "shadow prices", still vary by \$150/tCO_2.

Cooperative implementation of NDCs leads to a convergence in the marginal cost of carbon, shown as the solid red line, Figure 7 Panel (b). The size of the carbon market when countries reach net zero is shown in Figure 8. Figure 8 Panel (a & c) shows the near-term carbon market and Figure 8 Panel (b & d) shows the carbon market as global emissions approach zero.

Figure 7. Assumed regional NDCs limiting climate change to 2°C

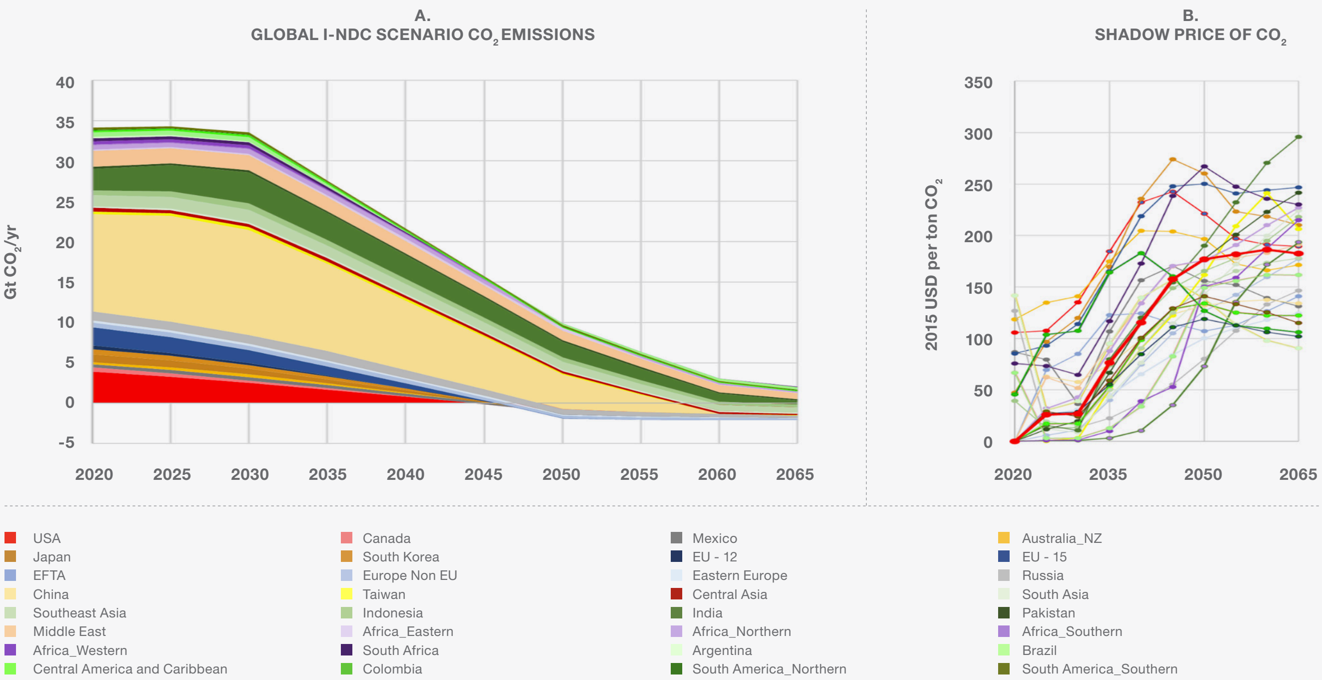
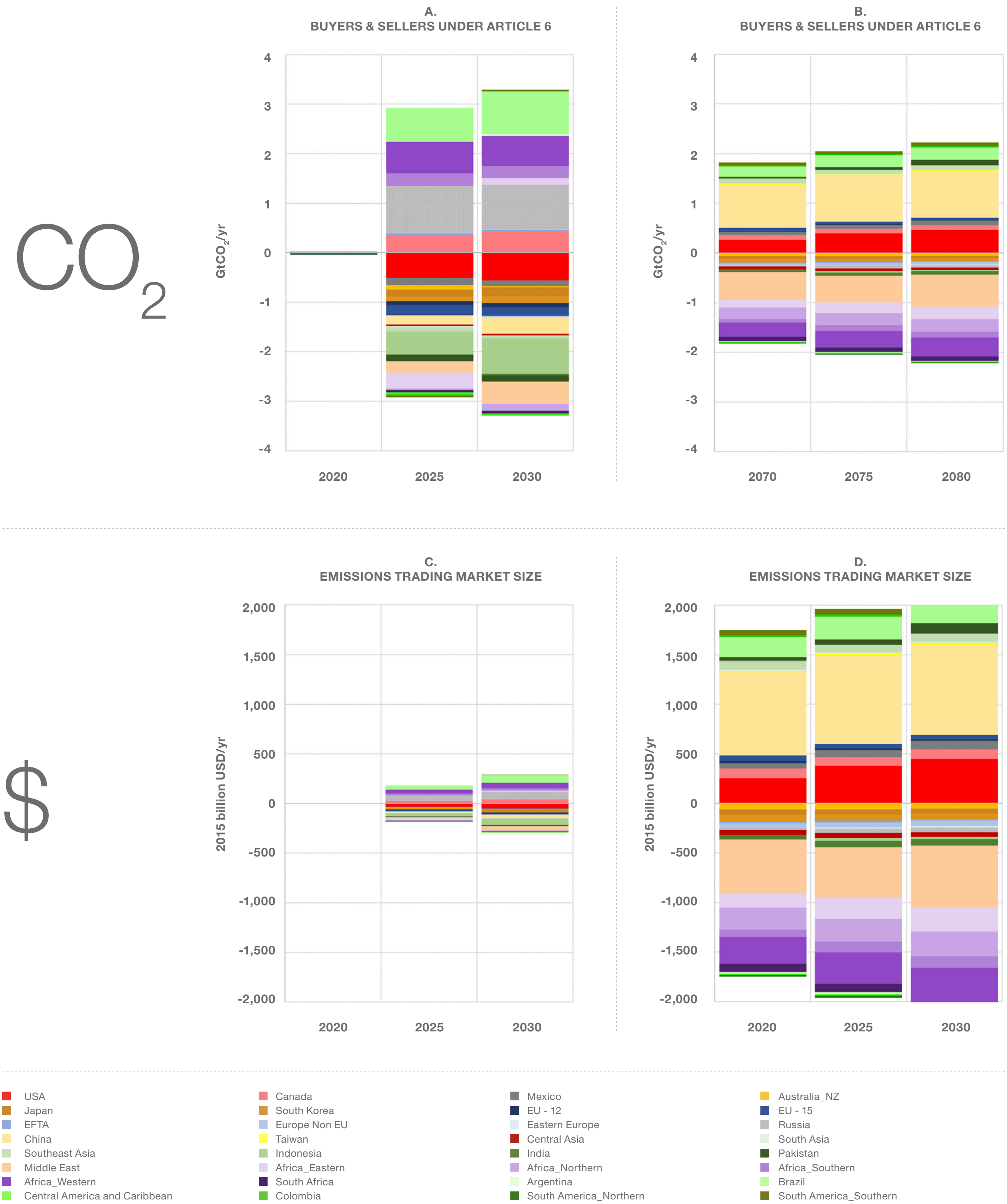


Figure 8. Physical carbon market trades when emissions approach zero compared to near-term carbon markets, 2°C limit



"The size of the long-term carbon market is smaller than in 2030. Yet the value of carbon transactions is greater."

The size of the long-term carbon market is smaller than in 2030. Yet the value of carbon transactions is greater. The increase in value emerges because of the higher value of carbon that emerges as parties' emissions approach zero, and the only remaining emissions are those which are hardest to reduce. Thus, the value of being able to being able to access negative emissions from parties that have, for example, afforestation opportunities or bioenergy with CO2 capture, is high.

When we increased ambition to limit climate change to 1.5°C of warming in 2100, similar results emerged. However, the GCAM model was unable to solve a scenario in which parties independently implemented NDCs that were sufficiently ambitious that climate change was limited to 1.5°C. This could occur for several reasons. For example, achieving 1.5°C with all regions acting independently might not solve because some regions have very difficult to mitigate sectors, for example methane emissions from landfills and abandoned coal mines, and no way to trade for offsets from other regions. We thus only report and examine results for the cooperative scenario. Those results are instructive.

Cooperative net-zero results are shown in Figure 9 Panel (a) and Panel (b). Physical trades by volume in 2050 are smaller than in 2030, reflecting the requirement that all parties' emissions must be near or below zero by 2050. However, the increasing marginal cost of carbon outpaces the reduction in market size.

Nature-based solutions play an important role in enabling net zero. Land systems hold the potential to store substantial amounts of carbon. Using Article 6 to engage those options can make it easier to achieve the 1.5°C goal. Figure 9 Panel (c) shows reductions in net fossil fuel CO2 emissions and offsetting terrestrial carbon sector CO2 removals (CDRs). Use of Article 6 increases the use of land-use change emissions uptake. Total forested area associated with our 1.5°C scenario is shown in Figure 9 Panel (d).

"When we increased ambition to limit climate change to 1.5°C of warming in 2100, similar results emerged. However, the GCAM model was unable to solve a scenario in which parties independently implemented NDCs that were sufficiently ambitious that climate change was limited to 1.5°C."

Figure 9. Carbon markets when change is limited to 1.5°C

Article 6 in a Fragmented World

Countries that employ Article 6 mechanisms to cooperatively meet their NDC goals are always able to benefit. Not every country need participate in cooperative mitigation for those engaged in cooperation to benefit.

The potential benefits from cooperation are greatest when all parties cooperate. There is no guarantee that will occur. In fact, the more likely outcome is that some parties engage in cooperative implementation of their NDCs and others do not. We have explored the consequences of partial cooperation both for the parties that continue to cooperate and those which do not. We have looked at the consequence of non-participation by potentially large buyers or sellers. We have also examined hypothetical global "clubs" formation.

Figure 10 shows the distribution of sales and purchases of ITMOs when all parties engage in cooperative implementation of their NDCs. The cooperative carbon price is \$27/tCO_2 in 2030 and \$175/tCO_2 in 2050. With this starting point, we systematically examine the consequence of a one-by-one removal of potentially large buyers and sellers from the cooperative club.

Large sellers include Russia, China, India, and Brazil. Buyers include the United States, Europe, and Canada. Figure 11 shows carbon market prices for the parties that remain in the cooperative coalition and for those that depart, for each of our sensitivities in 2030 and 2050. We have grouped sellers in Figure 11 Panel (a) and buyers in Figure 11 Panel (b).

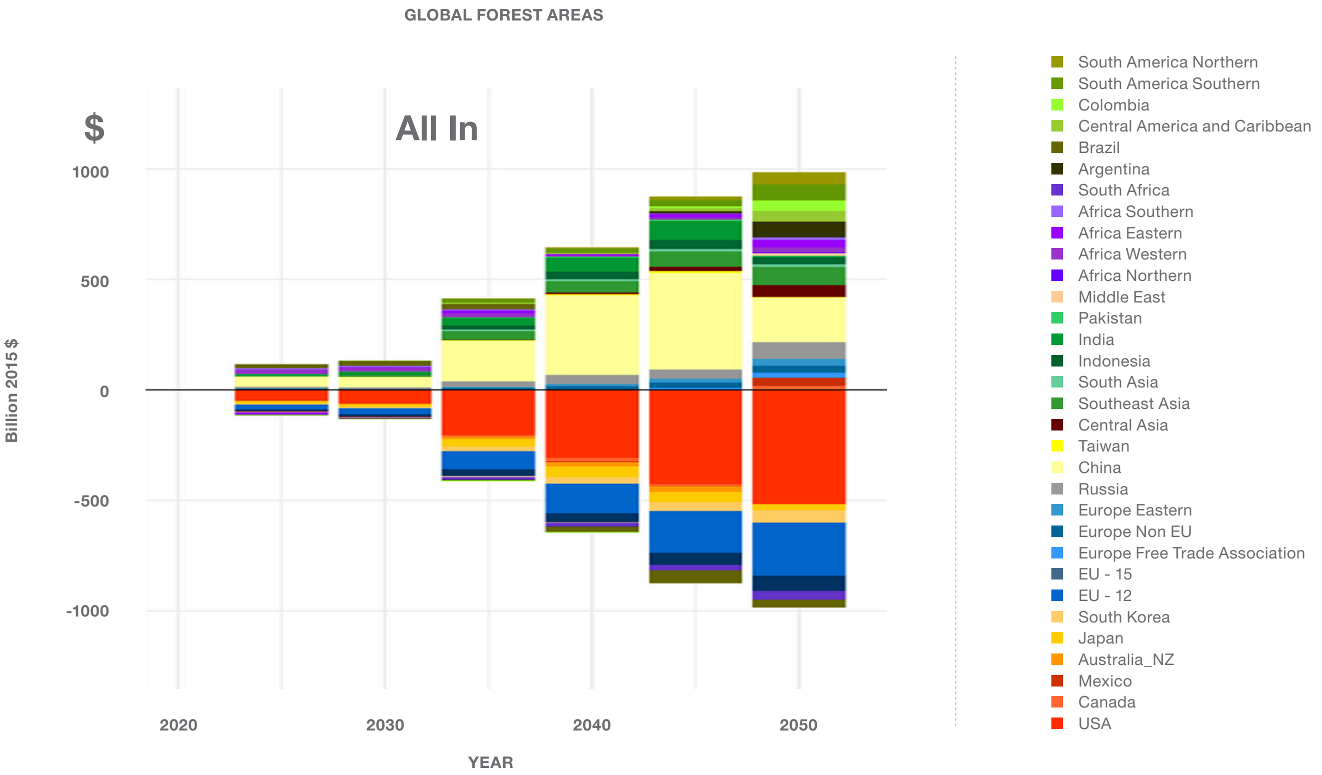
When major sellers leave the carbon market, the carbon prices seen by the remaining buyers and sellers rise. The increase in price is between \$1/tCO_2 (India and Russia) and \$10/tCO_2 (China). Other sellers benefit by seeing higher prices for their emissions mitigation beyond their NDCs. The party leaving the cooperative implementation market foregoes net benefits. Sales of ITMOs represent an important national export and contribute to sellers' GDPs. The value of sales can be large. For Russia, far from the largest seller, we estimate that lost sales amount to \$75 billion per year in 2050 and cumulatively \$850 billion between 2022 and 2050. China gives up the greatest potential ITMO sales over the period 2022 to 2050.

"Large sellers include Russia, China, India, and Brazil. Buyers include the United States, Europe, and Canada."

Buyers, on the other hand, face higher prices, but not as high as they would face were, they to implement their NDCs independently. The price faced by large parties choosing to "go it alone" is shown in Figure 11 Panel (b). Buyers remaining in the cooperative NDC implementation continue to have lower costs to achieving their NDCs.

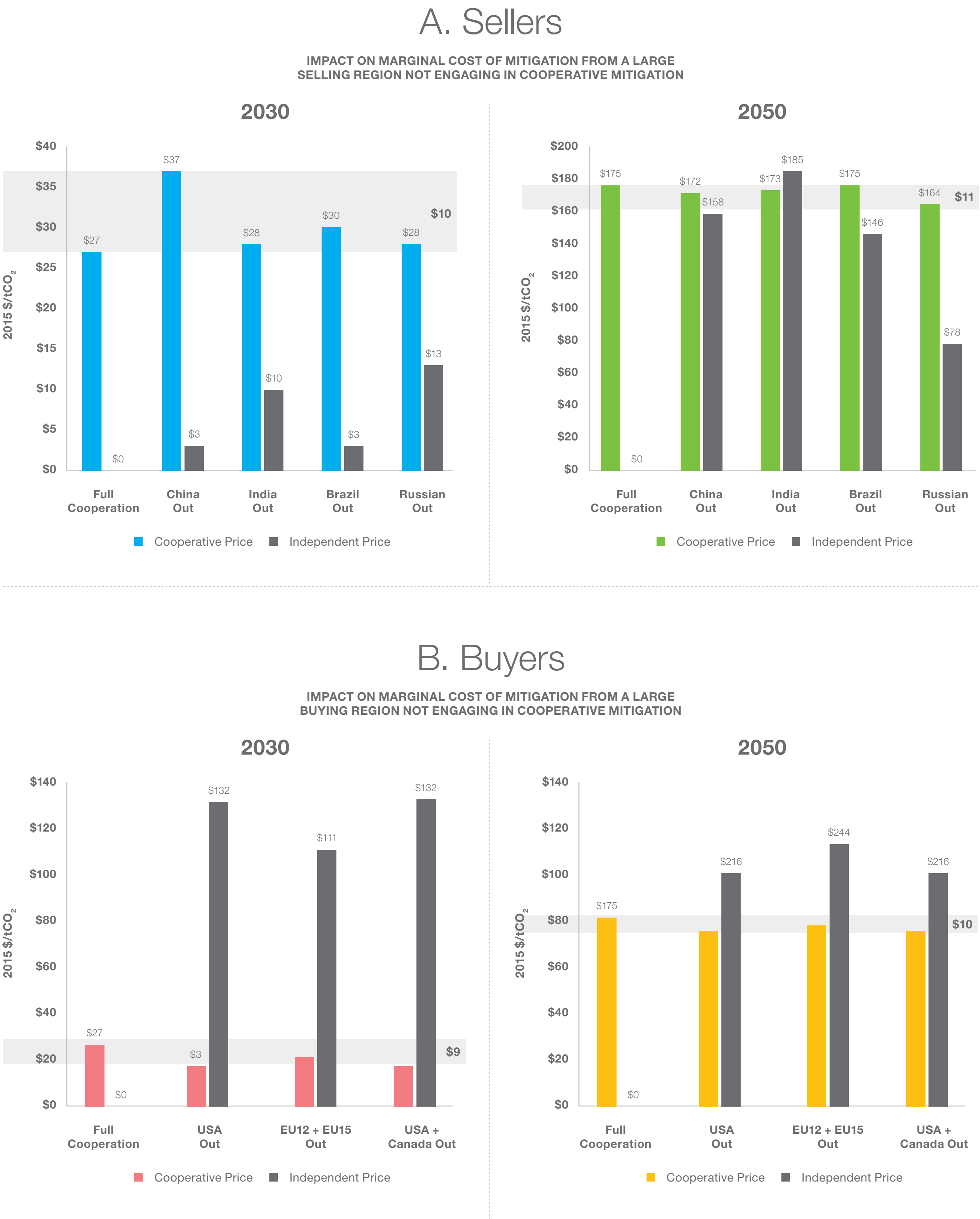
Despite the size of the individual buyers and sellers, the remaining parties see limited changes to their cooperative carbon price, Figure 11 Panel (d).

Figure 10. Purchases and sales of ITMOs with all parties' cooperative implementation



"Despite the size of the individual buyers and sellers, the remaining parties see limited changes to their cooperative carbon price"

Figure 11. Carbon prices when major buyers or seller do not participate in the cooperative implementation of NDCs



The degree of benefit and the role (buyer/seller) depends on the club in which a party cooperates.

In addition to exploring the sensitivity of the international carbon market to the departure of individual buyers and sellers, we have also examined the consequence of club formation. Clubs are sub-groups of parties to the Paris Agreement which join together to cooperatively implement their NDCs. To explore how the formation of clubs might affect the resulting cooperative implementation of NDCs and the roles individual parties played, we created a hypothetical scenario with two clubs. One club, which we refer to as the BRI Club, was assumed to form around China's "Belt and Road" program and the other contained the remaining parties[2], Figure 12.

"Clubs are sub-groups of parties to the Paris Agreement which join together to cooperatively implement their NDCs."

The CO_2 emission sales and purchases by BRI club members is shown in Figure 13 Panel (a & b) and the corresponding financial flows are shown in Figure 13 Panel (c & d). Figure 13 (a & c) are associated with global cooperation, showing sales (values greater than zero) and purchases (values less than zero) of ITMOs, while Figure 13 (b & d) show the associated outcomes for the BRI club case.

We observe the compared with the global cooperative implementation of NDCs, members of the BRI club engage in a smaller market. Sales of ITMOs are smaller than in the global cooperative implementation of NDCs. For example, sales by China diminish by 2050 Figure 13 Panel (b).

The role of parties can also be different than their role in a global cooperative implementation of NDCs. Sellers can become buyers, Figure 13 Panel (a).

2. The carbon clubs/ groups shown here are hypothetical and do not indicate any endorsement or likelihood of such associations. The BRI club was explored in the context of broader international alignments around the Russia-Ukraine conflict and is merely illustrative of one possibility. Alternate club compositions have also been examined by the authors, though not reported here, since the general conclusions are similar

Figure 12. Two hypothetical clubs: BRI and Non-BRI

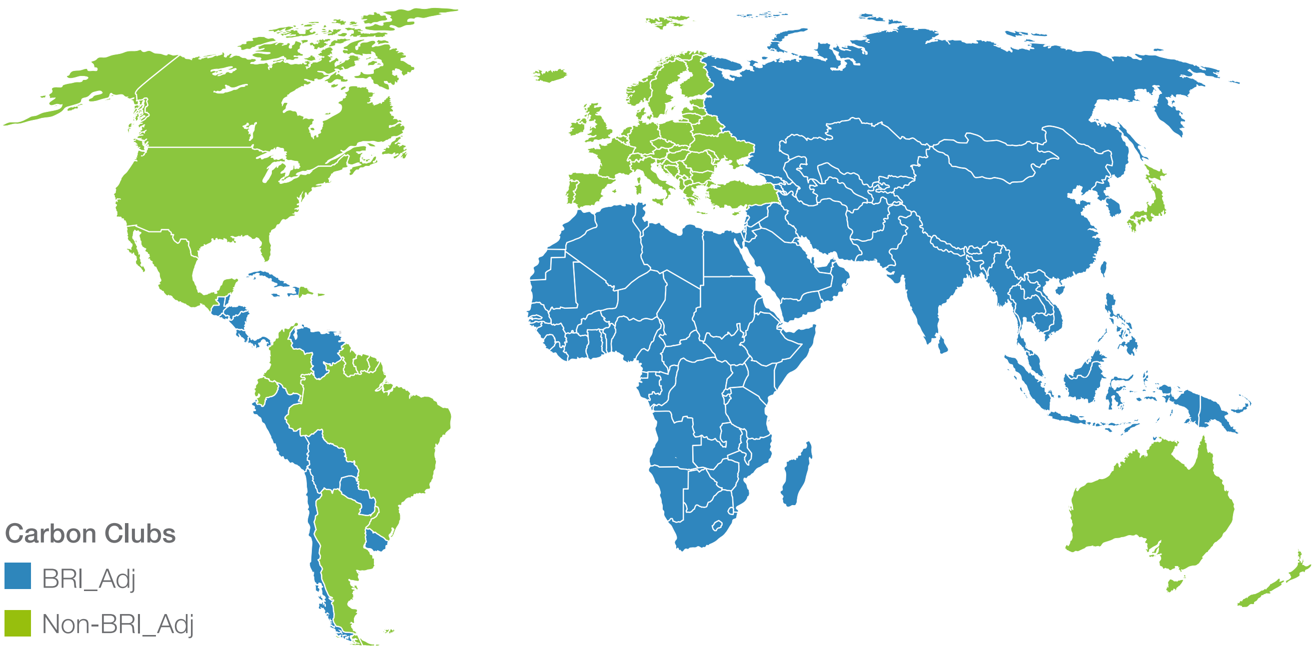
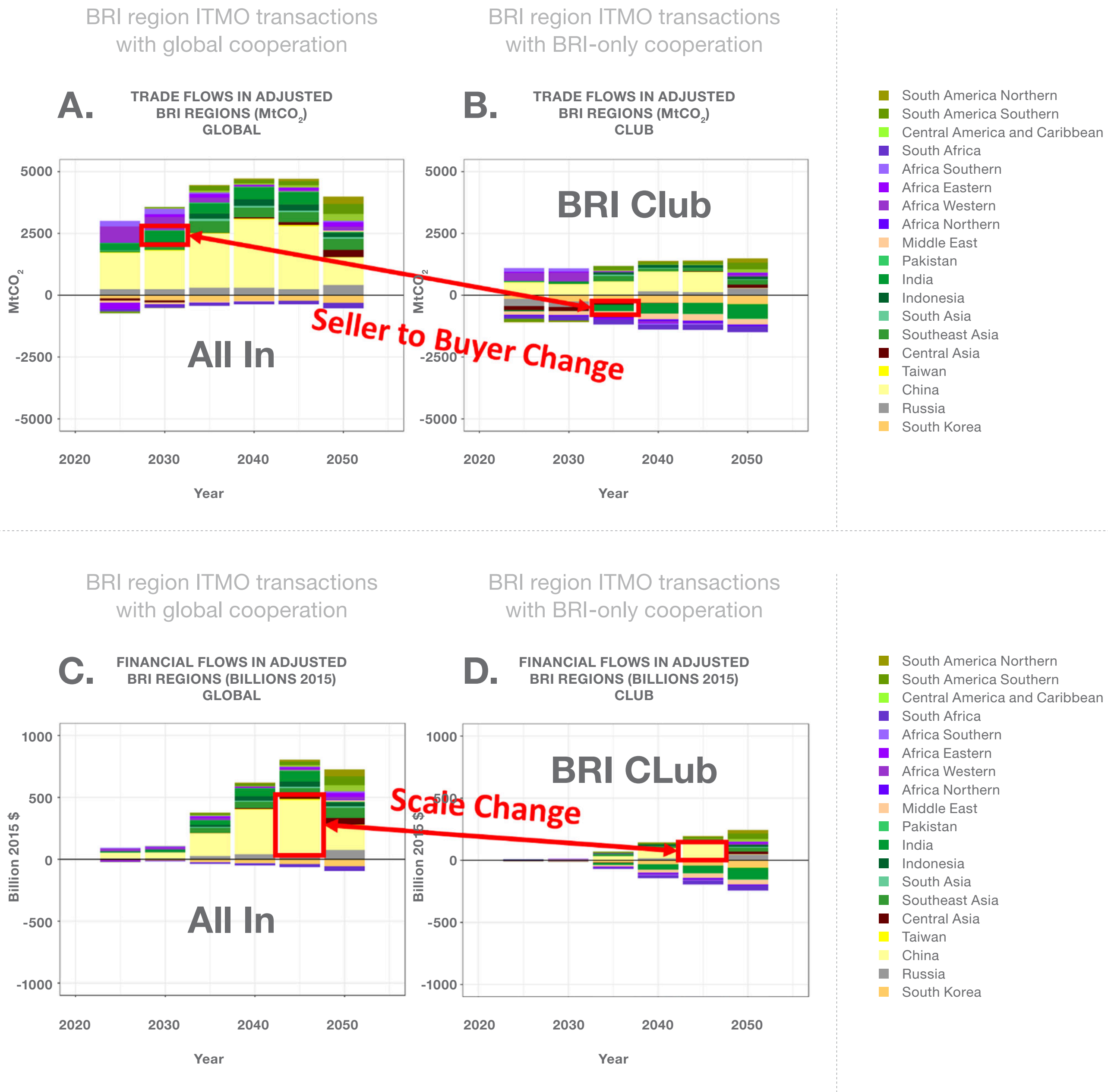
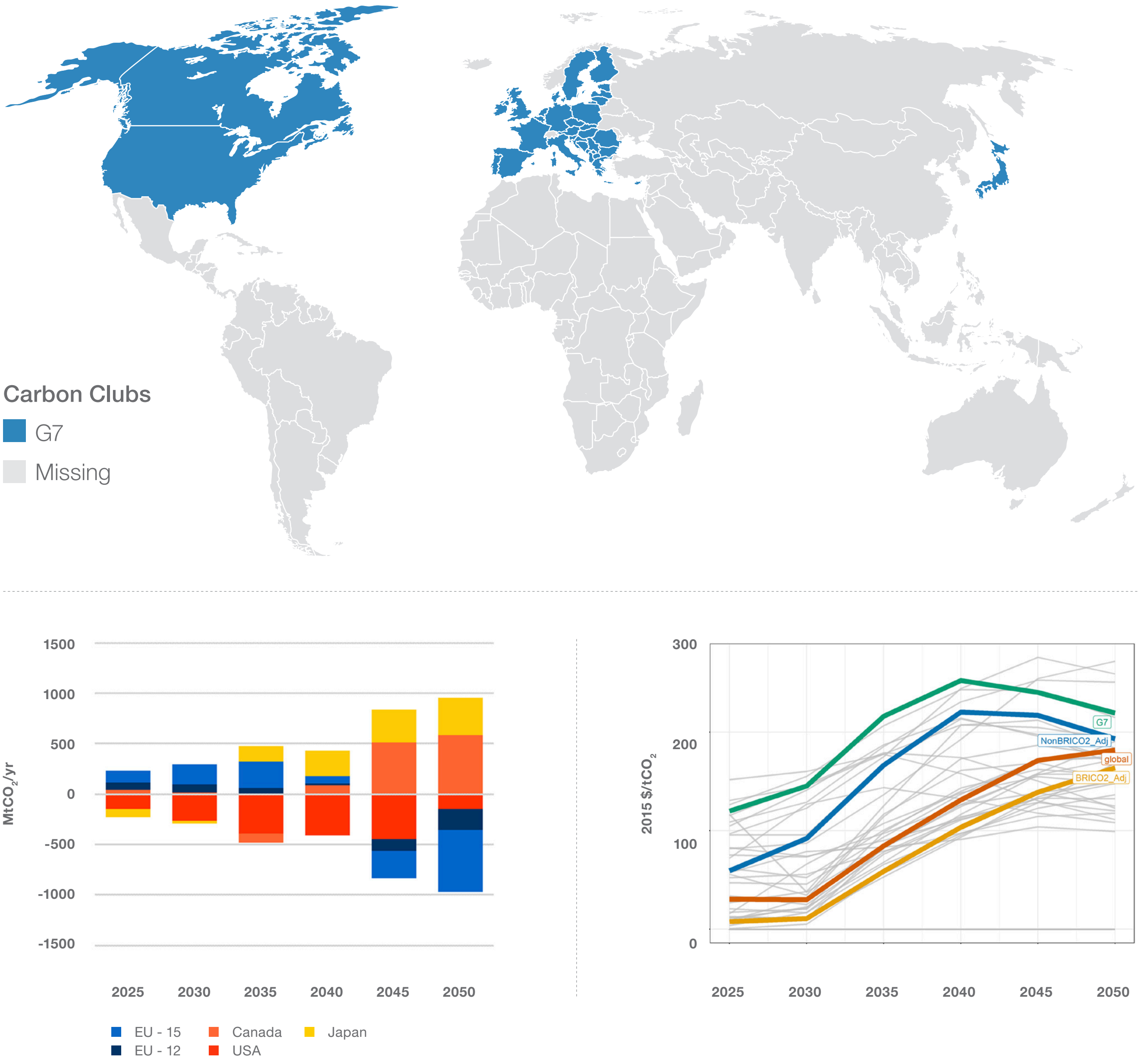


Figure 13. Two hypothetical clubs: BRI and Non-BRI



"We observe the compared with the global cooperative implementation of NDCs, members of the BRI club engage in a smaller market. Sales of ITMOs are smaller than in the global cooperative implementation of NDCs. "

Figure 14. The Hypothetical G7 Club



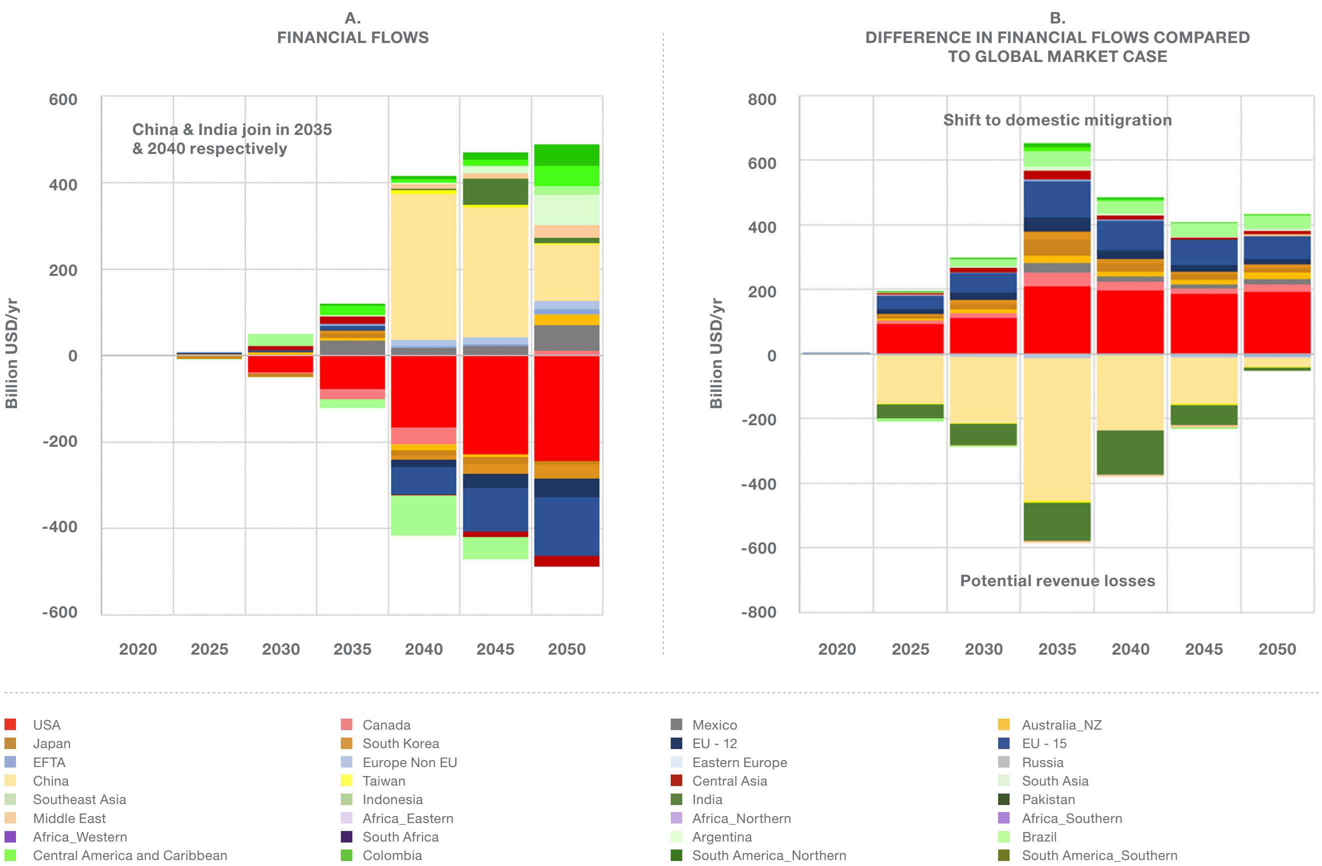
Club diversity is important and there are limited gains to North-North or South-South cooperation.

In contrast to the BRI club, which involves a predominant South-South cooperation, we also explored a club comprising the major industrialized economies, G7 nations, Figure 14, Panel (a). The volume of trade in a G7-only club was much smaller than the global case, although there are still gains from trading among the partners (Figure 14, Panel (b)). The gains are limited due to similarities in economic structures. For example, the carbon price in a G7-only club was much higher than the global case and similar to the high prices in individual regions (Figure 14, Panel (c)).

"The size of the long-term carbon market is smaller than in 2030. Yet the value of carbon transactions is greater."

We also examined a slowly growing "High Ambition Club", which starts with the G7 and gradually expands to encompass the entire G20 in stages through 2045. We observe that the trade volumes are much lower initially, in the absence of major developing economies (Figure 15, Panel (a)). When regions such as China and India join the club, the transfers increase significantly. However, compared to the global market, there are significant losses to these regions from their delayed entrance to the club (Figure 15, Panel b).

Figure 15. The hypothetical "High Ambition Club" starts with G7 nations and gradually expands to contain the G20 nations



Summing Up

Research over the past four years has increased understanding of the role Article 6 could play in facilitating the achievement of Paris goals. Important results flowed from this work. These include:

In the near-term, cooperative implementation of NDCs using Article 6 could substantially reduce resources needed to achieve emissions reductions compared to achieving the same global outcome with all parties implementing their NDCs independently.

If the savings from cooperative implementation of NDCs using Article 6 were reinvested in increased ambition, emissions mitigation could be more than doubled.

Creating an "ambition club" whose members pledged to increase ambition proportional to use of Article 6 emissions trades could help increase ambition over time.

If Article 6 is implemented in accordance with the letter and spirit of the Paris Agreement, the "low-hanging-fruit" (LHF) problem does not emerge. The LHF problem was an issue dating back to the Kyoto Protocol. The concern was that if parties with no emissions obligation undertook low-cost near-term emissions mitigation, they might later find themselves without such opportunities under a future emissions limit. The Paris Agreement is structured such that all parties have self-imposed goals from the beginning of the agreement. Emissions mitigation beyond an NDC, i.e. the higher-hanging fruit, are paid for by the buyers.

If buyers of emissions mitigation can only use a fraction of Internationally Transferred Mitigation Outcomes (ITMOs) purchases toward meeting their NDC, we find that the cost of achieving parties' NDCs rises. In this case, ITMO buyers do more domestic emissions mitigation, but ITMO sellers reduce their total emissions mitigation. The result is higher cost with no climate benefit.

Toward 2050, the role of Article 6 shifts to allowing parties to cooperatively achieve net zero emissions with removals. Countries with the ability to deliver negative emissions (or removals) can sell to parties with greatest difficulty in achieving zero emissions. Physical transactions in the market over this period shrink, but each ITMO is worth more. The overall value of transactions remains comparable to near-term levels.

Countries that employ Article 6 mechanisms to cooperatively meet their NDC goals always benefit, whether they are a buyer or a seller. Not every country need participate in cooperative mitigation for those engaged in cooperation to benefit.

If countries arrange plurilateral cooperative approaches (or "clubs"), the degree of benefit and the role (buyer/seller) depends on the club in which a party cooperates. Early club membership means that benefits arise earlier. Membership in a club with a wider range of marginal costs increases the potential benefits to be obtained.

As carbon markets continue to evolve, research can help guide its development.

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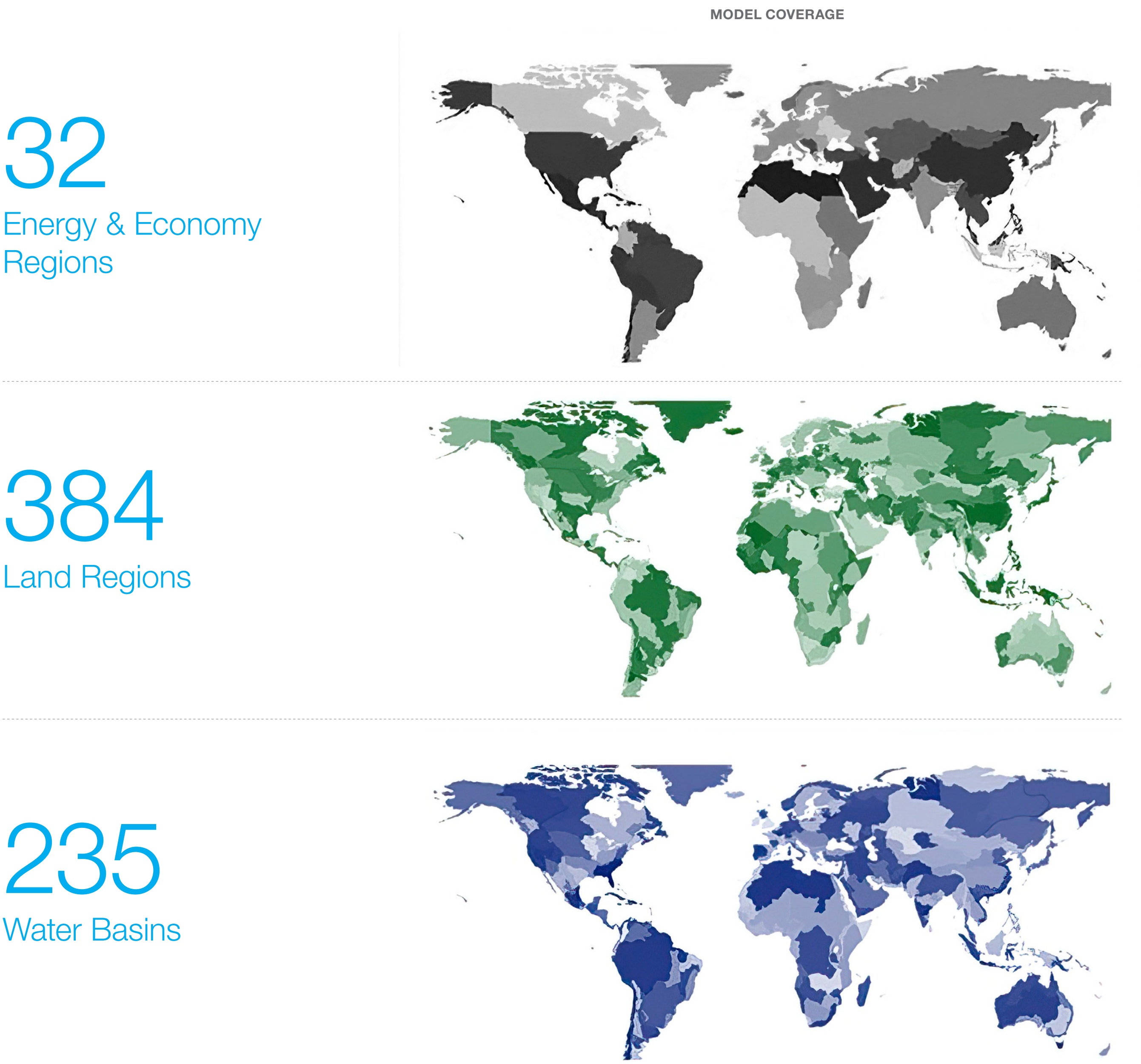
Appendix: The GCAM model

We have employed the Global Change Analysis Model (GCAM) using the most current version for each analytical exercise we performed. The current version of GCAM is v6.0. GCAM is an open-source, integrated assessment model, with global scope with disaggregation to 32 geopolitical regions, 384 land regions, and 235 water regions, Figure 16 (Calvin et al. 2019; Clarke and Edmonds 1993; Edmonds and Reilly 1983).

Figure 16. GCAM regional disaggregation



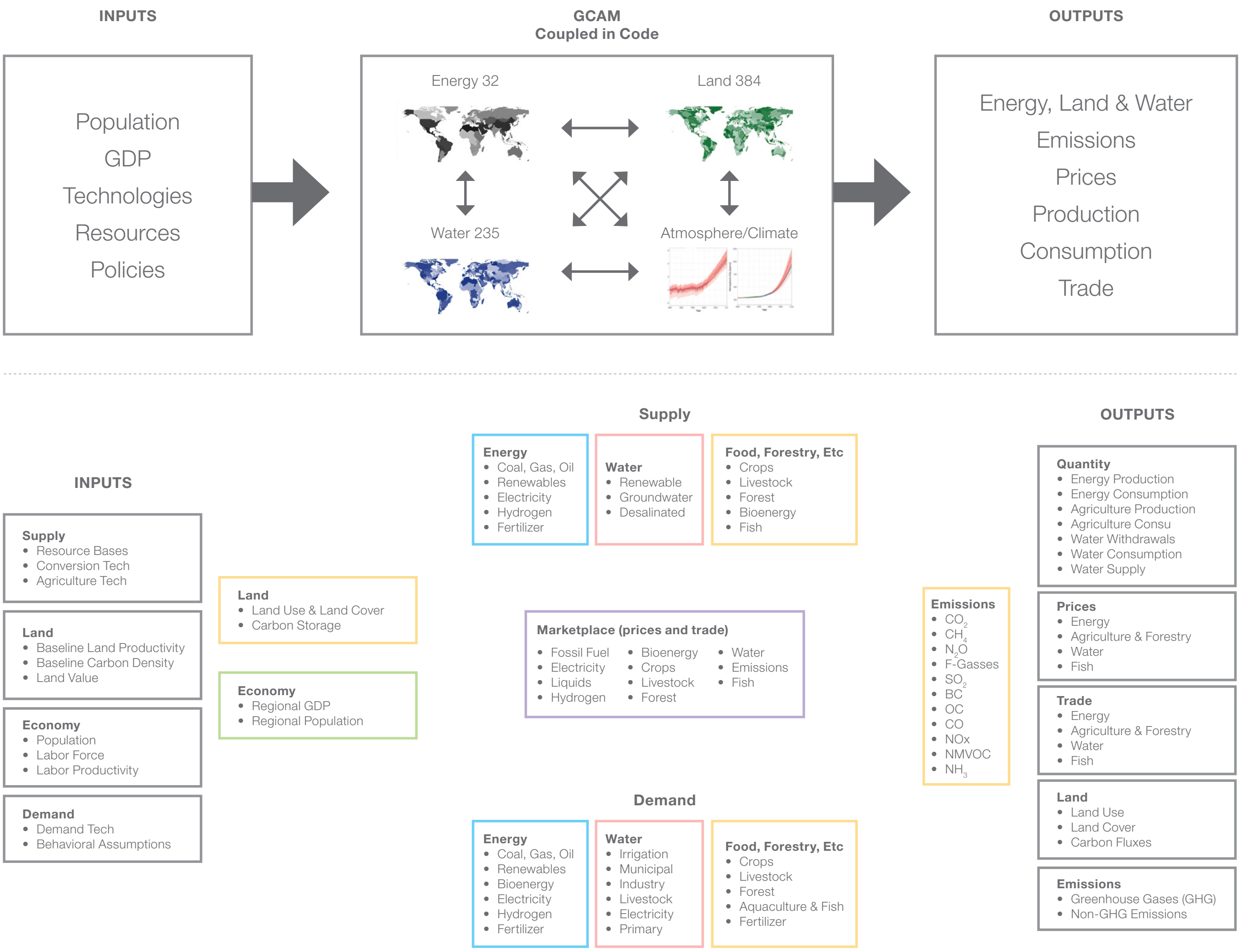
Appendix: The GCAM model

It links the energy, economy, agriculture, and land-use systems within a unified computational framework that solves all systems simultaneously and consistently, Figure 17.

The full documentation of GCAM is available on Github (http://jgcri.github.io/gcam-doc/). Full GCAM model documentation is available online (http://www.globalchange.umd.edu/gcam/indc/). GCAM is a dynamic-recursive model that solves each 5-year time step sequentially. The primary function of the GCAM solver is to find a vector of prices that simultaneously clears all markets in the system. GCAM is a physically based, hierarchical model which takes external assumptions about aggregate labor productivity growth and population in each region to establish the level of aggregate economic activity and then uses that information in combination with assumptions about technology, resource endowments, demand preferences and policies to produce supplies and demands for energy, agriculture, land, and hydrologic systems.

The reference scenario that is our counter-factual benchmark uses the GCAM representation of the Shared Socioeconomic Pathways Scenario 2 (SSP2), reported in Calvin, et al. (2017). By using the SSP2 scenario, it is comparable to other studies in the literature. While NDCs are a heterogeneous set of commitments, we have translated each NDC into an equivalent emissions reduction relative to a base year employing the updated Glasgow COP pledges reported in Ou & Iyer et al. (2021).

Figure 17. GCAM inputs, outputs, and major components



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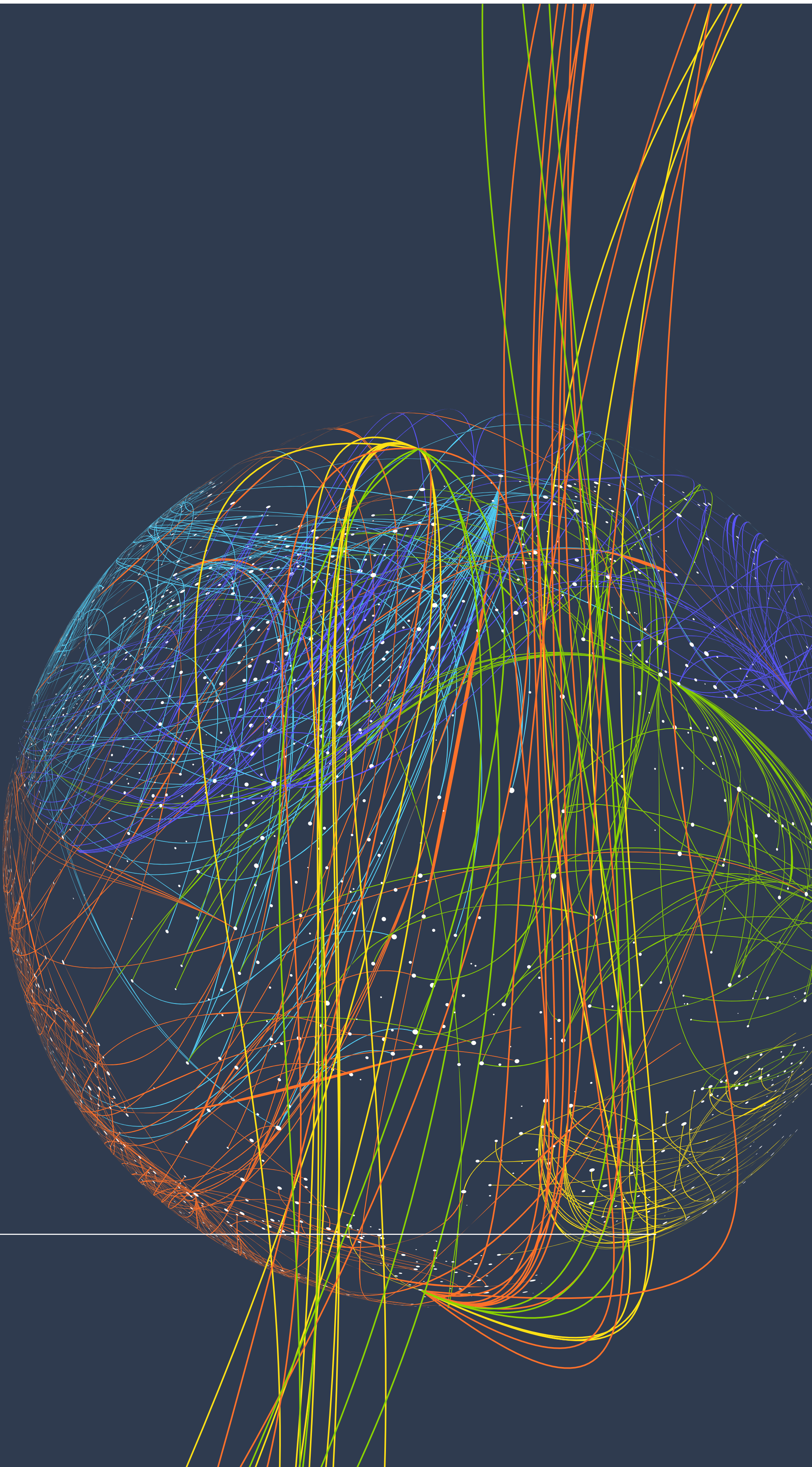

MODELLING THE ECONOMICS OF ARTICLE 6:
A CAPSTONE REPORT

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