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24, rue Merle d'Aubigné
CH-1207 Genève
Switzerland
Telephone: +41 22 737 05 00
Fax: +41 22 737 05 08
ieta.org

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Authors
This report was authored by Jonathan Camuzeaux, Dirk Forrister, Nathaniel Keohane, Ruben Lubowski, Jeremy Proville, Katie Sullivan, Jeff Swartz and Derek Walker.

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The complete report is available online at edf.org/doublingdown and ieta.org/doublingdown.

Table of contents

Executive summary

Many countries around the world are currently considering carbon pricing policies to achieve their greenhouse gas (GHG) emissions reduction goals, whether in the form of emissions trading systems (ETS), carbon taxes, or similar systems. On April 21, 2016, the High-Level Carbon Pricing Panel convened by World Bank Group President Jim Yong Kim and International Monetary Fund Managing Director Christine Lagarde announced the goals of doubling the amount of GHG emissions covered by carbon pricing mechanisms from current levels (about 12 percent[1]) to 25 percent of global emissions by 2020, and doubling it again to 50 percent within the following decade. This technical report details a range of possible, though non-exhaustive, scenarios for meeting these goals.

This report finds that the 25 percent-in-2020 goal can be achieved if existing and planned carbon pricing programs are augmented by additional actions. Specifically, the goal can be achieved if: existing carbon pricing programs are maintained; China implements its proposed national ETS on the power sector, domestic civil aviation, and six industrial subsectors; carbon dioxide (CO_2) emissions from international civil aviation are covered under a global market-based measure; *and* additional efforts are taken by other countries that are significant emitters.

Four scenarios are presented for additional action:

- **Scenario A.1:** Carbon pricing policies cover the entire U.S. power sector, and carbon pricing policies are implemented or extended as planned in the Canadian provinces of

Ontario, Manitoba, and Alberta (while current policies in British Columbia and Quebec are maintained);

or

- **Scenario A.2:** The EU nearly doubles the coverage of its ETS, including buildings, transport, and waste;

or

- **Scenario A.3:** China extends the coverage of its national ETS to include nearly all of its industrial sectors;

or

- **Scenario A.4:** A combination of major economies, such as Australia, Mexico, and Brazil, implement new or expanded carbon pricing policies.

Scenarios leading to 50 percent of global emissions covered in the following decade all assume the following baseline actions: Major emitting countries that currently have some form of carbon pricing policies extend their coverage to all energy and industrial emissions, and other countries with existing carbon pricing mechanisms retain these policies, *and* all emissions from international aviation and marine bunkers are covered by a carbon price.

To reach the 50 percent goal, four scenarios outlining additional country-level efforts are presented:

- **Scenario B.1:** Australia, Russia, Turkey, and Ukraine adopt extensive carbon pricing coverage and Brazil, India, Indonesia, and Thailand adopt policies with low levels of coverage;

or

- **Scenario B.2:** Australia, Russia, Turkey, and Ukraine adopt extensive carbon pricing coverage and Brazil and Indonesia cover 60 percent of their emissions from deforestation;

or

- **Scenario B.3:** All countries in Scenario B.1 cover at least 33 percent of their total GHG emissions;

or

- **Scenario B.4:** Tropical forest nations cover 100 percent of their emissions from deforestation.

The report concludes that the carbon pricing goals announced by the high-level Panel are *ambitious, but achievable.* Ambitious, in the sense that meeting the goals will require action beyond what is currently anticipated; achievable, in the sense that multiple carbon pricing scenarios exist that would meet the goals. At the same time, it is important to emphasize the limited scope of this report. The scenarios presented here are purely illustrative, and intended to demonstrate different combinations of policies that would meet the goals; they are not intended as predictions of what will happen. Perhaps more importantly, this report does not assess or make any assumptions about the level of stringency of the carbon pricing policies, the price level, or the emissions reductions achieved. Carbon pricing can help countries to implement their pledged emissions reductions targets and cut emissions even more in the future. But putting a price on carbon is a means to an end, not an end in itself. It will only be effective at realizing the promise of the Paris Agreement if the underlying policies are sufficiently ambitious.

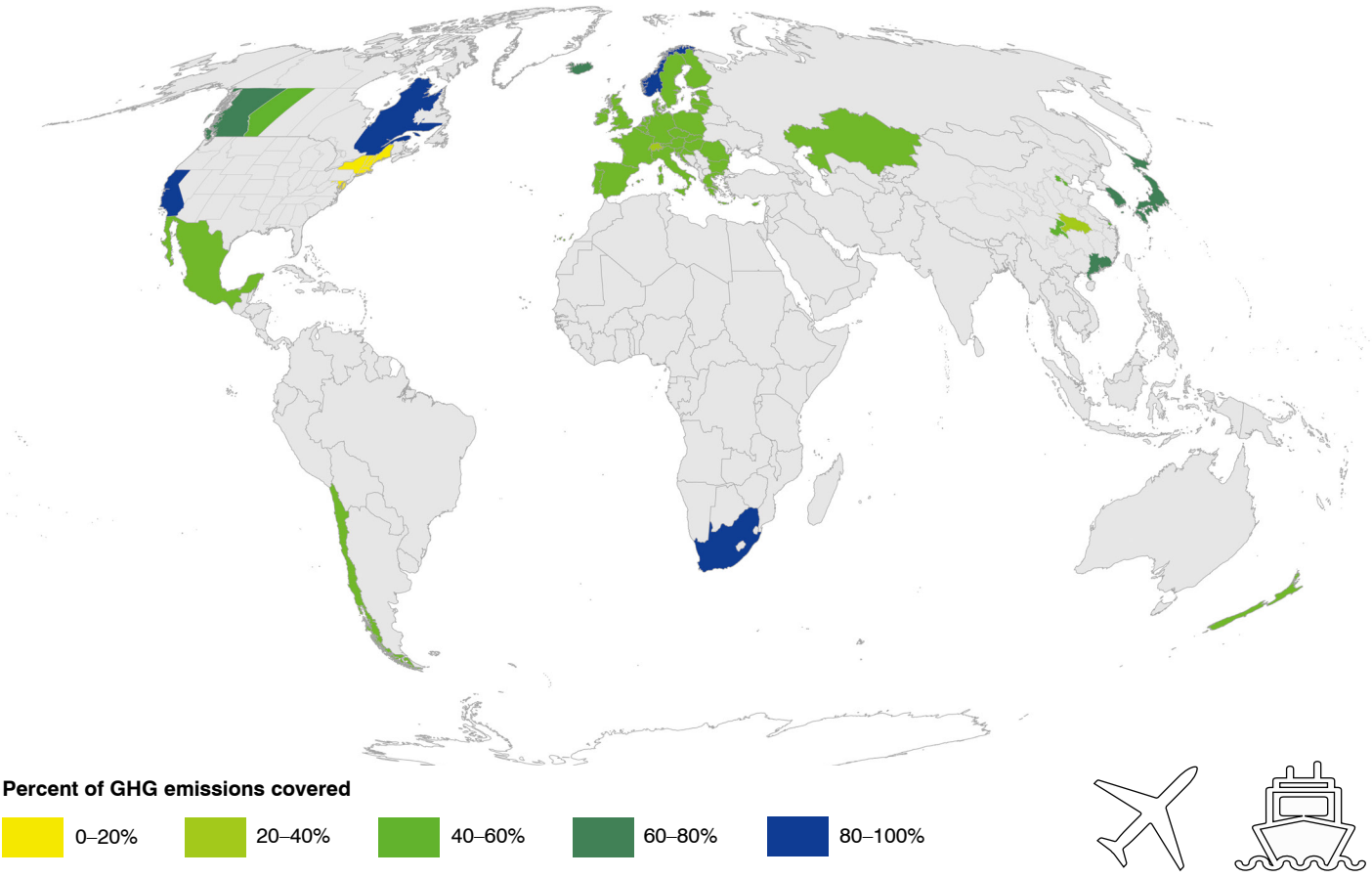
Introduction

The Paris Agreement on climate change, adopted on December 12, 2015, was a landmark in the fight against climate change. As countries prepare to implement their pledged emissions reduction targets known as Nationally Determined Contributions (NDCs) through domestic policies, many are likely to consider carbon pricing—either through an emissions trading system (ETS), baseline and credit systems, carbon tax, or combination of these policies. Indeed, 90 countries have already chosen to include some mention of market-based policies in their NDCs.

A price on carbon can be an attractive policy instrument for a number of reasons: it gives emitters a powerful economic incentive to reduce emissions at the lowest possible

FIGURE 1

Current carbon pricing coverage



cost; it promotes innovation while rewarding the development of even more cost-effective technologies; it drives private finance; and it can generate government revenue. And by aligning economic growth and emissions reductions, carbon pricing policies can ultimately promote cross-border cooperation and more ambitious climate action.

On April 21, 2016, the Carbon Pricing Panel convened by World Bank Group President Jim Yong Kim and International Monetary Fund Managing Director Christine Lagarde released a statement with ambitious goals on the extent of carbon pricing worldwide. Today, roughly 12 percent of global greenhouse gas (GHG) emissions are covered by an explicit carbon price, in the form of an ETS or a carbon tax, that has already been implemented or is scheduled to be implemented (Figure 1). In its statement, the Panel announced the goals of doubling the extent of carbon pricing to 25 percent of global GHG emissions by 2020, and doubling it again to 50 percent within the following decade. The members of the Panel include Prime Minister of Canada Justin Trudeau, President of Chile Michelle Bachelet, Prime Minister of the Federal Republic of Ethiopia Hailemariam Dessalegn, President of France François Hollande, Chancellor of the Federal Republic of Germany Angela Merkel, and President of Mexico Enrique Peña Nieto, together with Bank Group President Kim, IMF Managing Director Lagarde, California Governor Edmund G. Brown Jr., Rio de Janeiro Mayor Eduardo Paes and OECD Secretary-General Angel Gurría.

This technical report considers a range of potential scenarios for meeting the Panel's goals. It is intended to answer the question: **what are some possible scenarios under which the Panel's goals would be met?**

The scenarios presented are not exhaustive. Purely from an arithmetic perspective, it is possible to identify many possible scenarios that would result in a carbon price covering one-quarter or one-half of global GHG emissions. The scenarios presented are also not intended as predictions of what will happen. Rather, they are chosen to be broadly illustrative of potential combinations of carbon pricing policies by various countries. Finally, it is worth noting that the scenarios consider only the presence of a price on carbon, and not the strength of the target, level of the price, or emissions reductions achieved.

The remainder of the paper considers each goal in turn, and then offers brief conclusions. A technical appendix summarizes the data and methodologies used and provides detailed descriptions of the assumptions behind the scenarios.

Goal 1

Doubling the share of global GHG emissions covered by carbon pricing from 12 percent in 2015 to 25 percent in 2020

Multiple scenarios involving country-level actions could achieve a doubling of global emissions coverage between 2015 and 2020, all requiring carbon pricing adoption beyond what is currently implemented or scheduled to be implemented.

The scenarios mapped in Figure 2 illustrate four different ways of reaching 25 percent of global GHG emissions covered by 2020.[2] All of them assume the following:

- Existing carbon pricing programs, as illustrated in Figure 1 and detailed in the appendix, are maintained;

and

- China implements a national ETS covering CO_2 emissions from the power sector and select other sectors (as proposed by the country's National Development and Reform Commission (NDRC)), with total coverage assumed to amount to 50 percent of the country's total GHG emissions;[3]

and

- CO_2 emissions from international civil aviation are covered under the global market-based measure (MBM) currently under consideration by the International Civil Aviation Organization, which would achieve carbon-neutral growth by requiring the aviation sector to offset emissions above 2020 levels through verified emissions reductions elsewhere.[4] (Note: Because the MBM would be scheduled for implementation, we include it in our calculations of coverage in 2020, even though the measure would take effect from 2021.)

Additional efforts by major emitters are necessary to meet the 25 percent coverage by 2020 goal. Though there are many possible pathways, we present four alternative scenarios. Each of these, in combination with the actions described above, would result in 25 percent of global emissions covered:

- **Scenario A.1:** Carbon pricing is extended to the entire U.S. electric power sector, the Canadian provinces of Ontario and Manitoba introduce an ETS on 85 percent of their emissions, and Alberta increases the coverage of its carbon price to 78 percent of its emissions, while BC and Quebec maintain current policies (leading to 68 percent of Canada's total GHG emissions being covered) (Figure 2);

or

- **Scenario A.2:** The EU nearly doubles the coverage of its Emission Trading System (EU ETS) by including all CO_2, N_2O, and CH_4 emissions from industrial sources as well as from the buildings, transport, and waste sectors (Figure 2);

or

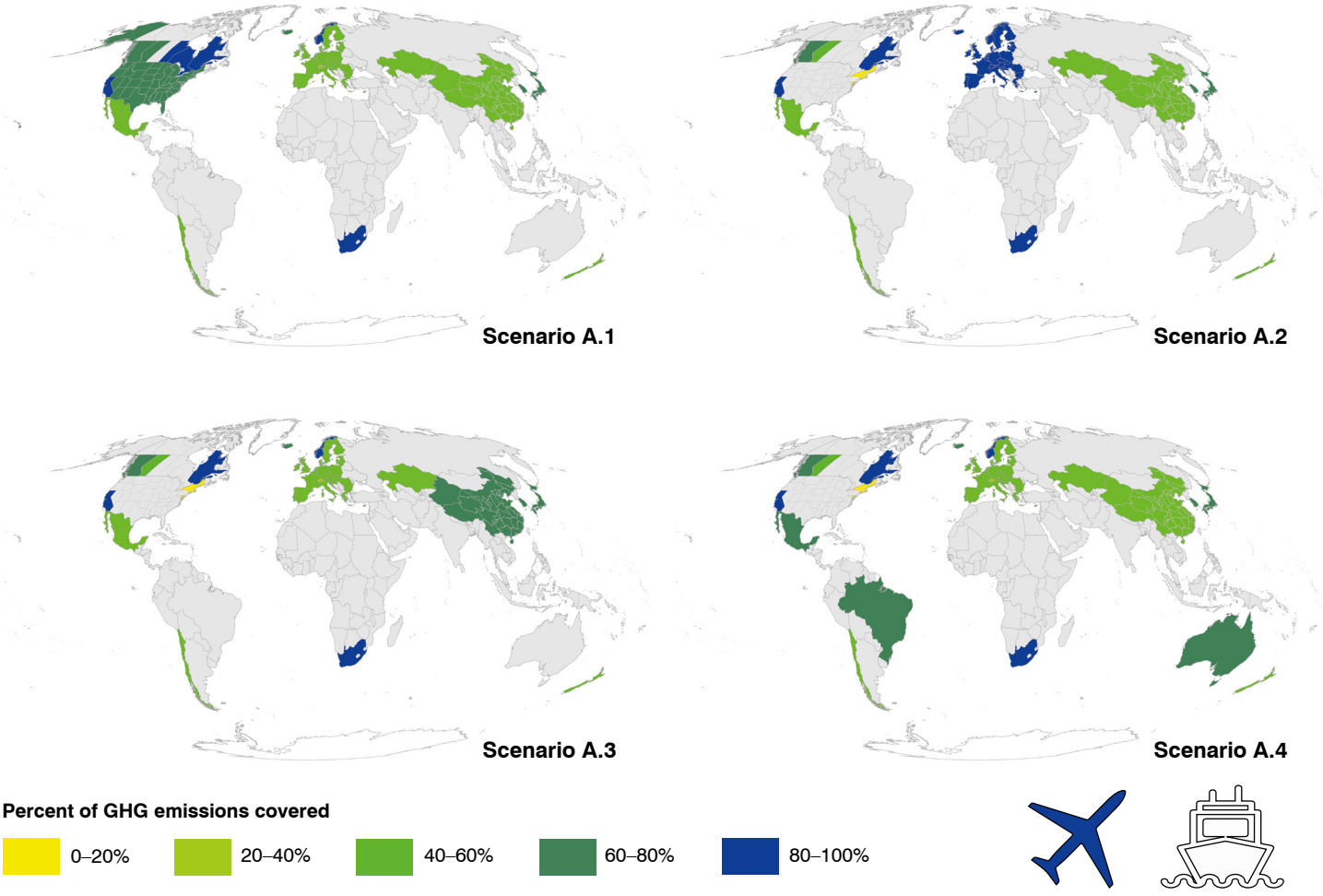
- **Scenario A.3:** China extends the coverage of its national ETS to be implemented to include 85 percent of industrial CO_2 and N_2O emissions, along with the power sector and domestic civil aviation (Figure 2);

or

- **Scenario A.4:** A combination of other major economies implements new or expanded carbon pricing policies—for example, Mexico extends a carbon price to 60 percent of its emissions, Australia introduces a carbon price on 60 percent of its emissions (the same coverage as under Australia's earlier ETS, since abolished), and Brazil introduces a carbon price on 60 percent of its emissions including from deforestation (Figure 2).

FIGURE 2

Scenarios achieving 25 percent of global GHG emissions covered by carbon pricing mechanisms in 2020



All scenarios assume existing carbon pricing mechanisms are maintained, China implements its announced national ETS, and CO_2 emissions from domestic civil aviation are covered under a carbon price. Scenario A.1 assumes expanded coverage in the U.S. and in Canadian provinces. In Scenario A.2, the EU doubles its current coverage by including additional sectors under its ETS. Scenario A.3 assumes China's national ETS extends its coverage in the industrial sector. In Scenario A.4, Mexico expands coverage and Australia and Brazil introduce carbon pricing on 60 percent of GHG emissions. See Appendix for details.

Goal 2

Doubling the share of global GHG emissions covered by carbon pricing to 50 percent in the following decade

Achieving another doubling of global emissions covered by carbon pricing mechanisms would require much more ambitious action beyond the 2020 goal. Again, there are multiple possible pathways at the country level that could reach this goal.

In Figure 3, we present four of these pathways, all of which assume the following baseline actions:

- Major emitting countries that have some form of carbon pricing policies today (including at the subnational level) extend their coverage to include all energy-related and industrial CO_2, CH_4, and N_2O emissions. This includes China, the EU, the U.S., Canada, Mexico, South Korea, Japan, and South Africa;[5]

and

- Other existing carbon pricing policies are maintained;

and

- All CO_2 emissions from international civil aviation as well as from marine bunkers are covered by a carbon price.

To meet the 50 percent coverage goal, other actions must also be taken by some combination of other countries with significant emissions. Each of the following four scenarios outlines efforts, which, in addition to the three baseline actions described above, would lead to half the world's GHG emissions included under some form of carbon price:

- **Scenario B.1:** Australia, Russia, Turkey, and Ukraine cover all energy-related and industrial CO_2, CH_4, and N_2O emissions. Brazil, India, Indonesia, and Thailand (all participants in the Partnership for Market Readiness (PMR)) cover 15 percent of their total GHG emissions (Figure 3);

or

- **Scenario B.2:** Australia, Russia, Turkey, and Ukraine cover all energy-related and industrial CO_2, CH_4, and N_2O emissions. Brazil and Indonesia include 60 percent of their CO_2 emissions from tropical deforestation under a carbon price (Figure 3);

or

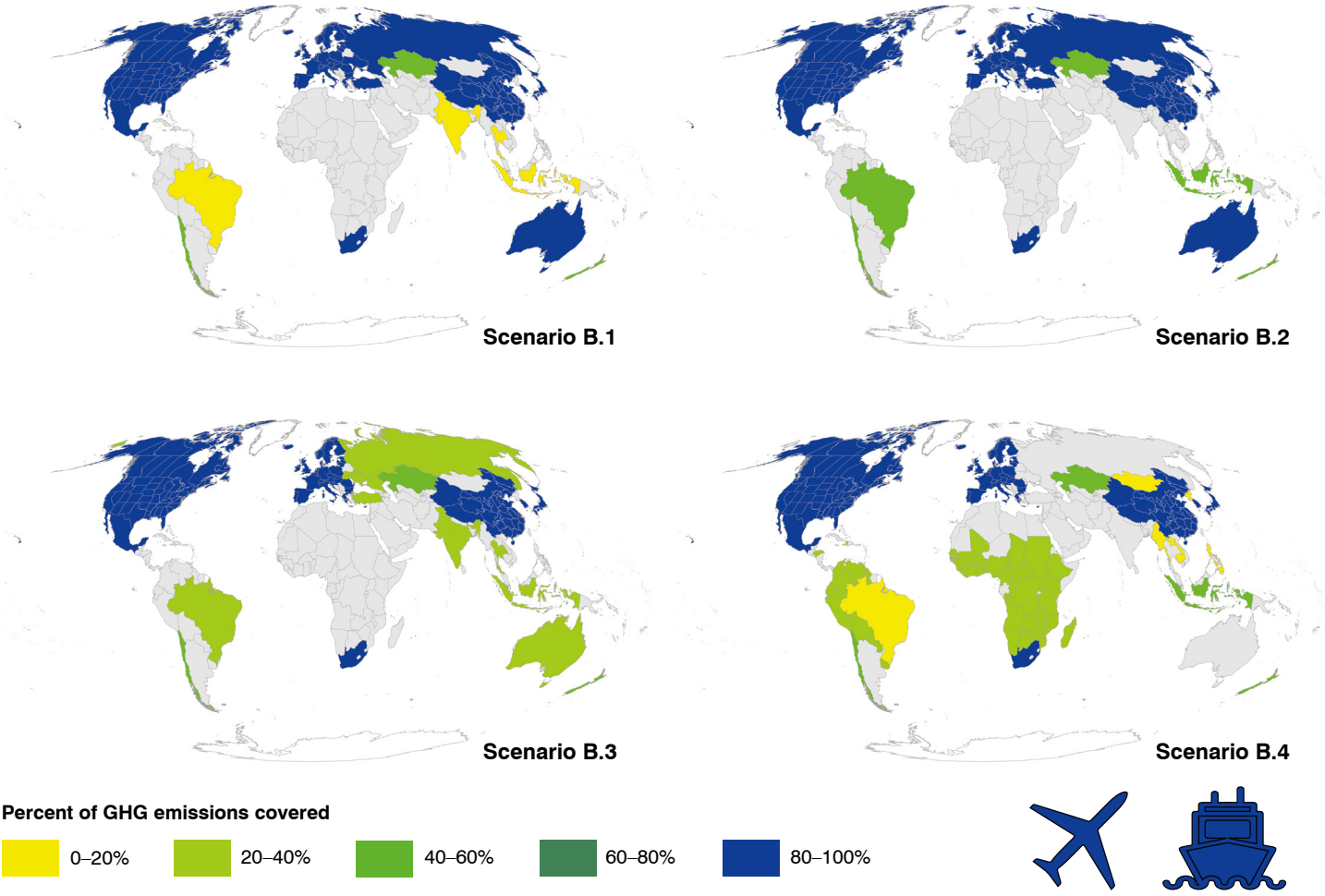
- **Scenario B.3:** Australia, Russia, Turkey, and Ukraine, as well as PMR countries Brazil, India, Indonesia, and Thailand, cover at least 33 percent of their total GHG emissions (Figure 3);

or

- **Scenario B.4:** Tropical forest nations in Latin America, Southeast Asia, and Africa cover 100 percent of their CO_2 emissions from tropical deforestation (Figure 3).

FIGURE 3

Scenarios achieving 50 percent of global GHG emissions covered by carbon pricing mechanisms



All scenarios assume that countries with some form of carbon price today maintain their policies, that major emitters among this group adopt extensive coverage of their emissions, and that CO_2 emissions from international aviation and marine bunkers are covered. Scenarios B.1 and B.2 both assume extensive GHG emissions coverage in Australia, Russia, Ukraine, and Turkey. This is complemented by low coverage in Brazil, India, Indonesia and Thailand in Scenario B.1, and partial coverage of Brazil and Indonesia's deforestation emissions in Scenario B.2. Scenario B.3 assumes all countries from Scenario B.1 cover one-third of their emissions. In Scenario B.4, tropical forest nations in Latin America, Southeast Asia, and Africa cover all their deforestation emissions. See Appendix for details.

Conclusion

The main conclusion from this analysis is that the carbon pricing goals announced by the Carbon Pricing Panel are *ambitious, but achievable.* Ambitious, because meeting the goals will require action beyond what is currently anticipated. This is true for the 2020 goal of doubling the coverage of carbon pricing to 25 percent of global GHG emissions—something that cannot be achieved only through China's announced national ETS and the global MBM for international civil aviation, along with existing carbon pricing policies. A goal of 50 percent coverage is even more ambitious, requiring countries with existing carbon pricing policies (including China, the EU, and the U.S.) to broaden coverage of those policies, while also requiring carbon pricing policies to be implemented in additional jurisdictions that have not yet done so.

At the same time, the existence of multiple plausible scenarios to meet the goals shows that they are achievable. The 25 percent-in-2020 goal could be met, for example, by stepped-up action in China, the EU, or North America (U.S. and Canada), or in a combination of other major emitters (e.g., Australia, Mexico, and Brazil). While the 50 percent goal is considerably more ambitious, and would almost certainly require significant action by all three of the world's largest emitters (China, the U.S., and the EU), it too could be achieved under a range of scenarios involving additional action by a range of various other countries (including major emitters such as Australia, Russia, Ukraine, Turkey, as well as others such as Brazil, India, Indonesia, or an array of tropical forest nations).

Achieving the carbon pricing goals considered here could be an important step in realizing the ambition of the Paris Agreement, which aims to hold the increase in the 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. Meeting that objective will require countries not only to implement the targets they have already announced, but to ratchet up their efforts dramatically in the years ahead. Carbon pricing will have to play a key role in that effort.

Countries can also raise ambition by connecting national carbon pricing systems, such as by linking carbon markets. Article 6 of the Paris Agreement provides a boost for such cooperation, recognizing the valuable role of market-based approaches (including the use of internationally transferred mitigation outcomes) in helping countries meet their NDCs, and providing for clear accounting rules to prevent "double-counting" of emissions reductions. This strong foundation for the use of markets creates a pathway for greater ambition on climate action over time.[6]

Of course, simply meeting the coverage goals considered here will not, by itself, be enough to realize the promise of Paris. Carbon pricing can help countries to implement their NDCs and cut emissions even more in the future. But putting a price on carbon is a means to an end, not an end in itself. It will only be effective at realizing the promise of the Paris Agreement if the underlying policies are sufficiently ambitious. The ultimate test of a carbon pricing program, like any climate policy, is the emissions reductions it achieves.

Technical appendix

I. Methods

We use estimates of global CO_2 and non-CO_2 GHG emissions data for the years 2015 to 2030, disaggregated into 36 national/regional entities (plus international civil aviation and marine bunkers), 4 gases or groups of gases, and 7 activity sectors (see Section II Data below for more details). The data are based on a scenario of future emissions consistent with countries' intended emissions targets announced in advance of the Paris Agreement of December, 2015. This provides a base scenario for countries' "business as usual" emissions under currently announced climate policies without further increases in the ambition of these policies that could be enabled via future carbon pricing efforts.

Building on these emissions projections, scenarios for country-level actions are derived by applying various levels of carbon pricing coverage (i.e. shares of emissions covered) to different combinations of geographical jurisdictions, sectors and gases. This provides estimates of the resulting percentage of total global emissions covered. A baseline percent coverage is established by determining what share of current emissions (2015) are included in carbon pricing mechanisms, whether under a cap or a tax and regardless of stringency. 2020 and 2025 scenarios are then derived by adding coverage to this baseline.

The scenarios simulated are hypothetical and intended purely for illustration. They are not predictions, and are presented with no prejudice as to their relative likelihood. Impacts of adopting carbon pricing mechanisms, such as issues of competitiveness and emissions leakage for example, are not considered.

II. Data

The geographical breakdown adopted in this report is consistent with that of Enerdata's Enerfuture dataset of annual energy and emissions forecasts through 2040, based on the Prospective Outlook on Long-Term Energy Systems (POLES) model, widely used by European governments for climate policy assessments. POLES is a partial equilibrium economic model of the global energy sector through 2050 developed in collaboration by the University of Grenoble-CNRS (EDDEN laboratory); the European Commission's Joint Research Centre, The Institute for Prospective Technological Studies (IPTS); and Enerdata (a consulting company which also offers the modeling results on a commercial basis).[7] Data sources and sector descriptions can be found in Table 1.

We use Enerdata's "Ener-Blue" scenario, which assumes the 2030 targets defined as part of the COP21 NDCs are successfully achieved. These estimates of energy sector emissions are combined with estimates of emissions from tropical deforestation and other land-use change and forestry emissions, assuming current emissions levels remain constant through 2030. Global emissions from this sector are projected to remain constant and even increase in the future in the absence of comprehensive carbon pricing or other policy actions. For simplicity, we do not consider the potential for policy actions to reduce emissions below current forest and other land-use change emissions as part of our "business as usual" scenario based on countries'

TABLE 1

Data description and sources by sector and greenhouse gas

Sectors and gases	Description	Source
Energy		
CO_2 power	CO_2 emissions in public electricity and heat production	Enerdata Enerfuture 2016
CO_2 transport	CO_2 emissions from transport	Enerdata Enerfuture 2016
CH_4	CH_4 emissions from oil and gas, coal mining, stationary and mobile combustion, biomass combustion, other	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
N_2O	N_2O emissions from stationary and mobile combustion, biomass combustion, other	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
Industry		
CO_2	CO_2 emissions from industry (incl. industrial process)	Enerdata Enerfuture 2016
CH_4	CH_4 emissions from industrial processes	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
N_2O	N_2O emissions from adipic acid and nitric acid production, other industrial processes	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
High GWP gases	High GWP gases (HFCs, SF_6, PFCs, NF_3) from industry and industrial processes	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
Buildings		
CO_2	CO_2 emissions from households, tertiary, agriculture	Enerdata Enerfuture 2016
Agriculture		
CH_4	CH_4 emissions from enteric fermentation, rice cultivation, manure management, other	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
N_2O	N_2O emissions from soils, manure management, other	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
Waste		
CH_4	CH_4 emissions from landfills, wastewater, other	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
N_2O	N_2O emissions from sewage and other	EPA Non-CO_2 Emissions and Projections (Dec. 2012)
Deforestation		
All GHGs	GHG emissions from deforestation	FAOSTAT 2014 (constant future emissions)
Aviation and marine		
CO_2	CO_2 emissions from international aviation and marine bunkers	ICAO, *Present and Future Trends in Aircraft Noise and Emissions*, 2013 (Aviation); IMO, Third IMO Greenhouse Gas Study 2014 (Maritime)

Non-CO_2 GHGs are converted to CO_2-equivalent units by using the 100-year Global Warming Potential (GWP) of each gas, consistent with the "EPA Non-CO_2 Emissions and Projections" report. CH_4 and N_2O emissions are updated to use GWP values from IPCC's Fifth Assessment Report (28 and 265 respectively).

already announced emissions targets. To the extent this increases our future global emissions projections relative to what current targets would potentially achieve, this is conservative from the perspective of estimating the difficulty of achieving global coverage of emissions under our different carbon pricing scenarios.

III. Detailed coverage scenario descriptions

(a) Current coverage

Current coverage (illustrated in Figure 1) is consistent with the "State and Trends of Carbon Pricing" report's list of countries with implemented or scheduled ETSs or carbon taxes.[8] In Europe, the EU ETS covers 45 percent of its GHG emissions (or roughly 2,120 $MMtCO_2e$). Norway, Iceland and Switzerland's GHG emissions are assumed to be covered at levels of 80, 75, and 38 percent respectively, through a combination of ETSs and carbon taxes in all three countries (a total of 75 $MMtCO_2e$). In the U.S., California's AB32 covers 85 percent of the state's emissions (390 $MMtCO_2e$), and the Regional Greenhouse Gas Initiative (RGGI) covers approximately 21 percent of its member states' GHG emissions (94 $MMtCO_2e$ in total). In Canada, ETSs in the provinces of Quebec, Alberta, and British Columbia cover 85, 43, and 70 percent of their emissions respectively, totaling 216 $MMtCO_2e$. Mexico's carbon tax covers 48 percent of the country's emissions (317 $MMtCO_2e$), and Chile's scheduled tax is assumed to cover 42 percent of the country's emissions (51 $MMtCO_2e$). 55 percent of Kazakhstan's emissions are covered by its ETS (202 $MMtCO_2e$). The Chinese ETS pilots vary in coverage, between 35 and 60 percent, and add up to 1,040 $MMtCO_2e$ included under a carbon price. South Korea's ETS is assumed to cover 66 percent of the country's GHG emissions (442 $MMtCO_2e$), and Japan's carbon tax covers 68 percent of its emissions (roughly 1,000 $MMtCO_2e$). Lastly, New Zealand's ETS and South Africa's scheduled tax are assumed to cover 54 and 80 percent of their emissions respectively (42 and 360 $MMtCO_2e$). Total current coverage is estimated at approximately 11.6 percent of global GHGs, or 6,157 $MMtCO_2e$.

(b) Goal 1

Each scenario consists of baseline actions (assumed to occur in every scenario) and additional efforts exclusive to each scenario, which, when combined, result in at least 25 percent of global GHG emissions included under a carbon price in 2020. Data sources can be found in Table 1.

Baseline actions

Existing carbon pricing programs, as described in (a), are maintained. China's national ETS is implemented and assumed to cover 100 percent of the country's power sector CO_2 emissions, 10 percent of its transport CO_2 (domestic civil aviation)[9] and 50 percent of its industrial CO_2, totaling 6,735 $MMtCO_2e$ covered, or 50 percent of China's 2020 GHG emissions. Lastly, all CO_2 emissions from international aviation—approximately 750 $MMtCO_2e$—are assumed to be covered under the global market-based measure currently under consideration by the International Civil Aviation Organization. (Note: While the current draft of the ICAO MBM includes some exemptions in the first phase, we have simplified the analysis by assuming complete coverage. Partial exemptions in this sector could be compensated for with corresponding increases in coverage elsewhere to reach the 25 percent goal.)

- **Scenario A.1:** The U.S. covers 100 percent of its CO_2 emissions from the power sector under a carbon price—California retains its ETS, covering 85 percent of the state's GHG emissions. This adds up to approximately 2,146 $MMtCO_2e$ covered, or 33 percent of the country's projected emissions for 2020. In addition, the Canadian provinces of Ontario

and Manitoba introduce an ETS that covers 85 percent of their GHG emissions (145 and 20 $MMtCO_2e$ respectively), and Alberta increases the coverage of its carbon price to 78 percent (224 $MMtCO_2e$). With British Columbia and Quebec maintaining their current policies, this results in 68 percent of Canada's GHG emissions being covered (506 $MMtCO_2e$). Total coverage for Scenario A.1 is calculated to equal 25.7 percent of global GHG emissions (or 14,321 $MMtCO_2e$).

- **Scenario A.2:** The EU (including EEA countries Norway, Iceland and Lichtenstein) expands the coverage of its ETS to include all power, transport, buildings, industry and waste CO_2, CH_4, and N_2O emissions, totaling 3,557 $MMtCO_2e$ covered for the region, or 85 percent of its GHG emissions. Total coverage for Scenario A.2 is calculated to equal 25.2 percent of global GHG emissions (or 14,064 $MMtCO_2e$).
- **Scenario A.3:** China extends its national ETS to include 85 percent of industrial CO_2 and N_2O emissions, increasing its coverage from 50 percent to 63 percent (or 8,335 $MMtCO_2e$ covered). Total coverage for Scenario A.3 equals 25 percent of global GHG emissions (13,928 $MMtCO_2e$).
- **Scenario A.4:** Mexico extends its carbon price to 60 percent of its emissions, or 511 $MMtCO_2e$. Brazil introduces a carbon price on 60 percent of its emissions, including deforestation, amounting to 1,150 $MMtCO_2e$ covered. Australia also introduces a carbon price on 60 percent of its emissions, amounting to 387 $MMtCO_2e$ covered. Total coverage for Scenario A.4 equals 25 percent of global GHG emissions (or 13,967 $MMtCO_2e$).

(c) Goal 2

As for Goal 1, we consider baseline actions (assumed to occur in every scenario) and additional efforts exclusive to each scenario, which, when combined, result in at least 50 percent of global GHG emissions included under a carbon price. In deriving scenarios, we calculated coverage percentages using GHG projections for both 2025 and 2030; the numbers cited below are for 2025. Data sources can be found in Table 1.

Baseline actions

China, the EU, the U.S., Canada, Mexico, South Korea, Japan, and South Africa extend their coverage to include all energy-related (power, transport, buildings) and industrial emissions of CO_2, CH_4, and N_2O emissions. These actions result in 36 percent of 2025 global GHG emissions covered by a carbon price (21,745 $MMtCO_2e$). In addition, Chile, New Zealand, and Kazakhstan retain their current policies (covering 307 $MMtCO_2e$) and all CO_2 emissions from international civil aviation and marine bunkers are covered by a carbon price (1,876 $MMtCO_2e$). In total, these baseline actions amount to 39.5 percent of global 2025 GHG emissions covered, or 23,928 $MMtCO_2e$.

- **Scenario B.1:** The following countries cover all energy-related and industrial CO_2, CH_4, and N_2O emissions: Australia (404.8 $MMtCO_2e$ covered), Russia (1,835 $MMtCO_2e$), Ukraine (351 $MMtCO_2e$), and Turkey (391 $MMtCO_2e$). In addition, 15 percent of total GHG emissions from the following PMR countries are covered: Brazil (296 $MMtCO_2e$ covered), India (677 $MMtCO_2e$), Indonesia (413 $MMtCO_2e$), and Thailand (63 $MMtCO_2e$). Total coverage for Scenario B.1 equals 51.2 percent of global 2025 GHG emissions (or 30,124 $MMtCO_2e$).
- **Scenario B.2:** Australia, Russia, Ukraine, and Turkey adopt extensive carbon price coverage as in Scenario B.1. Brazil and Indonesia include 60 percent of their CO_2 emissions

from tropical deforestation under a carbon price, or 184 and 1,009 $MMtCO_2e$ respectively. Total coverage for Scenario B.2 equals 50.8 percent of global 2025 GHG emissions (or 29,869 $MMtCO_2e$).

- **Scenario B.3:** All countries from Scenario B.1 cover 33 percent of their GHG emissions: Australia (216 $MMtCO_2e$ covered), Russia (729 $MMtCO_2e$), Ukraine (134 $MMtCO_2e$), Turkey (174 $MMtCO_2e$), Brazil (651 MMtCO2e), India (1,489 $MMtCO_2e$), Indonesia (908 $MMtCO_2e$), and Thailand (138 $MMtCO_2e$). Total coverage for Scenario B.3 equals 51.2 percent of global 2025 GHG emissions (or 30,131.3 $MMtCO_2e$).
- **Scenario B.4:** Tropical forest nations in Latin America (Mexico, Brazil, Colombia, Venezuela, Ecuador, Peru, Bolivia, Guyana, Paraguay, Uruguay, Honduras, Guyana, Haiti), Southeast Asia (Indonesia, Cambodia, Laos, Mongolia, Myanmar, South Korea, North Korea, the Philippines), and Africa (Angola, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Cote D'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Republic of the Congo, Rwanda, Senegal, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe) cover 100 percent of their CO_2 emissions from tropical deforestation. This amounts to 3,984 $MMtCO_2e$ from tropical deforestation covered under a carbon price. Total coverage for Scenario B.4 equals 50.5 percent of global 2025 GHG emissions (or 29,780 $MMtCO_2e$).

Notes

[1] See Alexandre Kossoy, et al., *State and Trends of Carbon Pricing 2015* (Washington, D.C.: World Bank, 2015). To ensure consistency, this report uses the same approach to calculating carbon pricing "coverage."

[2] This analysis considers carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and high-global-warming-pollutant gases (e.g., chlorofluorocarbons). If only some gases are assumed to be covered, they are specified.

[3] Proposed sectoral coverage reported in Carbon Pulse, "China lists national ETS industries, outlines rules for verifiers." Available at http://carbon-pulse.com/14353/.

[4] ICAO Website, "Market-Based Measures." Available at: http://www.icao.int/environmental-protection/Pages/market-based-measures.aspx.

[5] The assumed coverage of all energy-related and industrial emissions of CO_2, CH_4, and N_2O is roughly similar to the coverage of California's ETS (although it is slightly broader, e.g. in coverage of fugitive methane emissions from the oil and gas sector). For comparison, the EU-ETS currently includes CO_2 emissions from the power sector, plus a portion of industrial emissions (CO_2, N_2O, and PFCs), plus CO_2 emissions from intra-EU civil aviation; it does not cover methane emissions. Assuming coverage of energy-related and industrial emissions of CO_2 only would reduce coverage by approximately 3 percent, requiring correspondingly broader coverage on other dimensions.

[6] See Environmental Defense Fund and IETA, "Carbon Pricing: The Paris Agreement's Key Ingredient" (April 2016).

[7] For a recent application, see: Criqui, P., Mima, S., Menanteau, P. & Kitous, A. (2015). Mitigation strategies and energy technology learning: an assessment with the POLES model. *Technological Forecasting and Social Change*, vol. 90 Part A, pp. 119–136. Also, see: http://www.enerdata.net/enerdatauk/solutions/energy-models/poles-model.php.

[8] Alexandre Kossoy, et al., *State and Trends of Carbon Pricing 2015* (Washington, D.C.: World Bank, 2015).

[9] See He Ji-Cheng and Xu Yu-Qing, "Estimation of the Aircraft CO_2 Emissions of China's Civil Aviation during 1960–2009," *Advances in Climate Change Research* 3(2):99–105 (25 June 2012). Figure 4 in that paper shows that civil aviation accounted for roughly 8% of China's transportation emissions for the period 1995-2005; we have used 10% here as a rough estimate and to account for growing demand for air travel.