CDP
DRIVING SUSTAINABLE ECONOMIES

# CARBON PRICING CORRIDORS

## THE MARKET VIEW 2018

WE MEAN BUSINESS

CPLC CARBON PRICING LEADERSHIP COALITION

# THE CARBON PRICING CORRIDORS INITIATIVE

## Leading businesses and investors are working out how to align themselves with the objectives of the Paris Agreement.

Carbon pricing has emerged as a key mechanism to reduce greenhouse gas (GHG) emissions, which means that private and public stakeholders are seeking an informed view of how carbon-related price signals can drive global emissions reductions in line with these goals. In 2017, CDP and the We Mean Business Coalition launched the Carbon Pricing Corridors initiative with the aim of enabling large market players to define the carbon prices needed for industry to meet the goals of the Paris Agreement. Many companies and financial institutions are already adapting to this new paradigm by assessing risk within a 2°C constraint[1] and seeking low-carbon opportunities.

The inaugural report was published in May 2017 with a focus on the power sector, considered by some as the foundation of the low-carbon transition. This new report features an update on the power sector a year following the initial inquiry process and a new Corridor for the chemical sector.

The Carbon Pricing Corridors initiative aims to provide a valuable benchmark for businesses and investors seeking to make strategic decisions consistent with a low-carbon economy but struggling with a lack of information about the risks and opportunities involved in this transition. The initiative can also inform governments turning to carbon pricing as a mechanism to achieve their climate goals as well as those seeking to reform existing carbon pricing policies to strengthen market signals.

The initiative's work complements the framework of recommendations developed by the Task Force on Climate-related Financial Disclosures (TCFD or Task Force), which outlines the need for enhanced stress testing of climate-related risks and opportunities. The Carbon Pricing Corridors can be used as a tool in scenario analysis as organizations consider the potential financial, strategic, and business impacts of the Paris Agreement on their decisions.

The Corridors panel is made up of 29 chief executives and senior leaders from leading companies, the investment community, and international experts from across the G20 economies. These individuals are at the forefront of carbon-related change and have joined forces with their peers to advance thinking on decarbonization within their industries. The Corridors is an invaluable initiative for companies and investors actively seeking to stay ahead and instigate innovative changes across the global business community.

Panel members contributed to the Corridors process by responding to a small set of quantitative and qualitative questions and participating in a spoken interview. The results discussed in this report are intended to identify and shape an aggregate projection for a range of carbon prices from 2020 through 2035 to help guide two of the most polluting sectors to set a meaningful and effective decarbonization trajectory.

1 A 2°C scenario lays out an energy system deployment pathway and an emissions trajectory consistent with limiting the global average temperature increase to 2°C above the pre-industrial average.

"Our CEO, Feike Sijbesma, and I believe that the Corridors initiative is very valuable to companies and investors who are seeking to prepare for a low-carbon economy, which is why we joined as a founding panel member right from the start. We already include the financial impact of carbon emissions through a €50/ton CO2 internal carbon price when reviewing large investment decisions. As a global industrials company, we are keen to join initiatives that advance our own thinking on how to "future proof" DSM."

— **Geraldine Matchett,** CFO and Member of the Managing Board, Royal DSM

## CORRIDORS PANEL MEMBERS

**ABYD KARMALI**
Managing Director of Climate Finance, Bank of America Merrill Lynch

**ANDRE DORF**
CEO, CPFL

**ANDREW N. LIVERIS**
Chairman and Chief Executive Officer, The Dow Chemical Company

**BRUNO SARDA**
VP of Sustainability, NRG Energy

**BOB INGLIS**
Former Republican Member of the US House of Representatives and Executive Director, rebublicEN

**CARLA BARRETTO**
Member of the Board, Braskem

**ELSE BOS**
CEO, PGGM

**FEIKE SIJBESMA**
CEO, Royal DSM

**GERALD CARTIGNY**
Member of the Managing Board, CIO, MN

**GÉRARD MESTRALLET**
Chairman, Engie

**IAN YADIGAROGLU**
Managing Principal, Capricorn Investment Group

**JEAN-PIERRE CLAMADIEU**
CEO, Solvay

**JEROEN DE HAAS**
CEO, Eneco

**IGNACIO SANCHEZ GALAN**
CEO, Iberdrola SA

**JOSE MANUEL ENTRECANALES DOMECQ**
CEO, Acciona

**MARK LEWIS**
Head of Research, Carbon Tracker; Member of the Task Force on Climate-related Financial Disclosures

**MATS ANDERSSON**
Former CEO, AP4

**MICHAEL GRUBB**
Professor of International Energy and Climate Change Policy, University College London

**NANCY PFUND**
Managing Partner, DBL Partners

**PEKKA LUNDMARK**
CEO, Fortum Oyj

**PHILIPPE JOUBERT**
Chair, The Global Electricity Initiative

**RAMAKRISHNAN MUKUNDAN**
Managing Director and CEO, Tata Chemicals

**RANA KAPOOR**
Managing Director and CEO, YesBank

**ROSS ROLFE**
CEO, Infigen Energy

**SAKER NUSSEIBEH**
CEO, Hermes Investment Fund

**SHERARD COWPER-COLES***
Group Head of Government Affairs, HSBC Holdings Group

**VLADISLAV SOLOVIEV***
CEO and Chairman of the Management Board, United Company RUSAL

**YASUHIKO KITAURA**
Managing Executive Officer, Process Production and Safety Dept, Sumitomo Chemical Company

**YOUSEF AL-BENYAN**
Vice Chairman and CEO, SABIC

* Participating as an observer

# EXECUTIVE SUMMARY

"Stress testing, built off better disclosure and a price corridor, could act as a time machine, shining a light not just on today's risks, but on those that may otherwise lurk in the darkness for years to come."

— **Mark Carney,** Governor of the Bank of England and Chair of the G20's Financial Stability Board

**1. Companies and investors must anticipate and mitigate the financial risks driven by climate change.** This requires adapting to significant physical environmental changes and wide-ranging, unpredictable shifts in market conditions as we transition to a low-carbon economy. Market actors need to prepare for a range of potential scenarios.

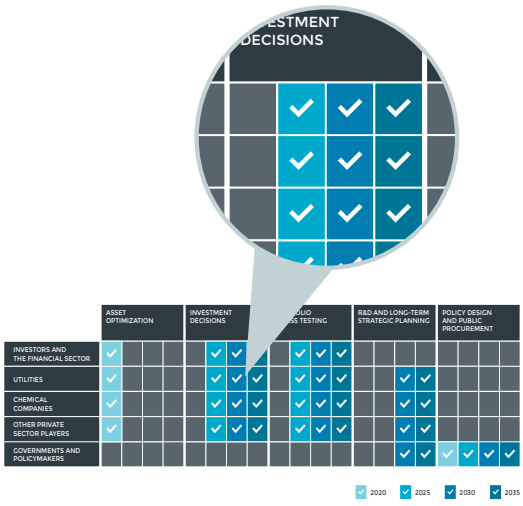
**2. The Task Force on Climate-related Financial Disclosures (TCFD) outlines a framework of recommendations to manage climate-related risks and opportunities,** including the application of internal carbon pricing in scenario analysis. The TCFD recommends that organizations use scenario analysis to test their business models and investments against a range of forward-looking scenarios – including a 2°C scenario (assuming a framework in line with the ambitions of the Paris Agreement).

**3. Internal carbon pricing has emerged as a forward-looking metric that can help organizations manage climate-related transition risks and opportunities.** In 2017, nearly 1,400 companies disclosed using or planning to use an internal carbon price. Companies can use an internal carbon price as a risk and opportunity proxy for (1) government policies that put an explicit price on carbon, via emissions trading systems and taxes, and additionally, (2) implicit carbon pricing signals in the economy that may arise from shifting technological, regulatory and market dynamics. The combination of these factors and explicit carbon pricing policies creates a signal indicating the present and future costs of carbon.

**4. The Corridors Panel is composed of 29 senior business leaders and experts** exploring how investors and companies can use a range of carbon prices, over different time horizons (the Carbon Price Corridor), as a metric to price transition risk into operational and investment decisions. They have provided insider views into how carbon-related price signals will and need to develop if we are to achieve the transformational emissions reduction goals that governments and private sector actors have set themselves, as defined by the Paris Agreement on climate change.

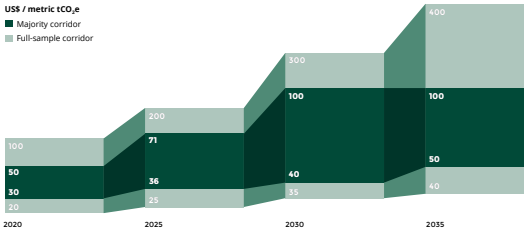
**5. This report includes a new Corridor for the chemical sector and an updated Corridor for the power sector.** These can be used by a wide range of actors with an interest in the changes taking place in these markets – including business and financial actors seeking to align their business and investment strategies with the Paris Agreement, and policymakers, as they seek to align policy frameworks to achieve their climate goals. For further reference, the initiative developed a 'user matrix' detailing how different sectors could use the Corridors, over various time periods, to benchmark their business decisions against carbon-related price signals.

**User matrix**



**6. In the short-term (2020), 50% of panelists from the chemical sector needed** USD 30-50/tonne as the carbon price corridor needed to strategic planning and investment decision-making and catalyze emissions reductions. These price signals will need to steadily increase over time, reaching USD 50-100/tonne for 2035, to drive the innovation and investment needed to decarbonize in line with the Paris Agreement. Panel members noted that the diverse and complex nature of the chemical industry makes it challenging to define a common decarbonization pathway for widespread reference.

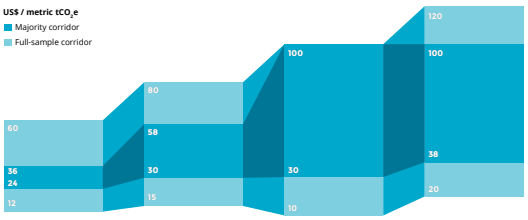
### Chemical 2018 Corridor




**Note:** upper range of full-sample corridor is not shown to scale

**7. Power sector respondents strongly considered market and economic factors in determining the price level needed to drive change** (e.g. developments in underlying economic factors such as power and commodity prices and the levelized cost of renewables). 50% of the power sector panel identified USD 24-35/tonnes as the needed range of carbon price signals in the short-term (2020) to drive fuel switching and renewables deployment, rising to USD 38-100/tonne by 2035 reflecting the case for other technologies such as battery storage or CCS.

### Power 2018 Corridor




**8. In both sectors there is uniform recognition of the need for increasing carbon pricing signals,** but there is a lack of confidence that this is likely to be achieved via explicit carbon pricing policies in the short-term. While there is more optimism for the medium- to long-term, there is widespread agreement that additional policy mechanisms will be needed to drive investment decisions and the decarbonization of both the power and chemical sectors. This has implications for long-term capital investments being made today.

**9. Ensuring that investments are robust in the face of these price ranges** will be important to support the financial performance of companies and portfolios in the medium- to long-term. This in turn will help enable the transformation of the economy, improve the ability to identify low-carbon innovation opportunities, and decrease systemic climate risk.

"Carbon pricing corridors are key to managing the transition risk to 2°C: with the vision they give, they allow gradual transformation of companies' business models and avoid the damaging effects of abrupt changes in economic and regulatory environments, while securing a level playing field for all actors. In ENGIE we decided to use internal carbon pricing and it led to us making the decision not to develop coal any longer, gradually switching from coal to other low-carbon technologies and favoring even more renewable developments."

— **Gerard Mestrallet,** President, ENGIE

# CONTENTS



This communication is a collective view of the Corridors initiative, and may not represent the individual viewpoints of Corridors Panelists and/or their respective organizations.

# 01 MANAGING CLIMATE RISKS EFFECTIVELY

"For too long, the global financial markets have been seen as separate to wider society, which is simply not true. The financial world is part of the real world and the decisions we take in it affect the economy and social cohesion. Those of us privileged enough to be trusted with the savings of everyday citizens have a responsibility to invest their capital responsibly. These are the people who will hold us to account if we do not tackle climate change – it is part of our jobs as the stewards of their capital to do so."

— **Saker Nusseibeh,** CEO, Hermes Investment Management

## THE COST OF CLIMATE CHANGE

Climate change is widely recognized as one of the most significant economic and social challenges facing the world today. Earlier this year, pension funds in New York City announced legal action against five of the biggest oil companies for climate change-related damages and announced that the city would divest USD 5 billion from companies associated with the fossil fuel industry.[2] Following a record year of natural disaster damage in the United States, valued at over USD 300 billion dollars, ratings agencies Moody's Investors Services and S&P Global Ratings have indicated potentially integrating disaster forecasting into individual ratings.[3]

In response to the inevitable rising and unpredictable costs of pollution, almost every nation in the world has signed the Paris Agreement since 2015 – committing to hold "the increase in thte global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels."[4]

Although the potential impacts of climate change are widely recognized, the massive scale and long-term nature of the problem make it difficult to frame in financial terms in today's markets, which tend to focus on short-term business cycles. This presents a serious challenge for actors in both the public and private sectors seeking consistent and quantifiable climate-related information to incorporate into their risk management strategies. To avoid the most dangerous and costly impacts of climate change, economic actors need informed decision-making today – so investors can correctly value assets, companies can invest in low-carbon business strategies, and policymakers can design effective climate policies.

## ONE POLICY SOLUTION: CARBON PRICING

As the international community starts to implement the Paris Agreement, carbon pricing has emerged as a key policy mechanism in driving GHG emissions reductions in the private and public sectors. A carbon price assigns a monetary value to each tonne of carbon dioxide emissions, thereby allowing the associated costs to be factored into the economic rationale of actors making investment, business, and policy decisions. As such, carbon pricing is a powerful tool for assessing climate-related risks and opportunities.

Governments allocate a cost to carbon pollution – through emissions trading systems or taxation – to incentivize polluters to reduce the amount of carbon they emit in what economists deem to be the most flexible and least-cost way to society. Well-designed policies have the potential to stimulate market innovation and develop low-carbon drivers of economic growth.

Regulations that put a price on carbon currently exist in 42 countries at the national level and 25 areas at the subnational level, almost doubling since 2012. With several new systems in development – including trading schemes in China and Mexico among others – it is expected that 20%-25% of global carbon emissions will soon be covered by a carbon price.[5] Additionally, more than one hundred

2 William Neuman, "To Fight Climate Change, New York City Takes On Oil Companies," The New York Times, January 10, 2018.

3 Emily Chasan, "Climate Change Could Make Borrowing More Expensive," Bloomberg Businessweek, January 23, 2018.

4 The United Nations Framework Convention on Climate Change, "The Paris Agreement," December 2015.

5 World Bank, Ecofys and Vivid Economics. 2017. State and Trends of Carbon Pricing 2017 (November), by World Bank, Washington, DC.

"Last year's One Planet Summit in Paris saw over 50 companies calling for meaningful carbon prices that "provide direction towards a well-below 2-degree world." Similarly, the WEF CEO Climate Leaders called for a price towards (at least) USD 40 per ton. I urge all business leaders to echo this message in their policy engagement at national levels. Now is the time to engage visibly and constructively: in the run-up to COP24, governments are focusing on the implementation of the Paris Agreement and on raising their national ambition levels."

— **Feike Sijbesma,** CEO and Chairman of the Managing Board, Royal DSM

nations that signed the Paris Agreement plan to use carbon pricing and other market mechanisms to achieve their emissions reduction goals, as stated in their 'nationally determined contributions' (NDCs).[6] Some governments, including the UK and several US States,[7] use a 'social cost of carbon' in their regulation assessment processes, to measure anticipated damages of incremental increases in carbon emissions.

Despite this momentum, price levels vary considerably across economies, leaving businesses and investors faced with a highly uncertain and heterogeneous context for making strategic decisions. Additionally, three-quarters of the emissions facing an explicit carbon price have a price below USD 10/tonne,[8] which economists highlight as significantly too low to incentivize low-carbon investments at the needed scale to meet the Paris Agreement.[9]

Carbon emissions can also be priced implicitly via energy taxes, support for renewable energy, and energy efficiency standards. In some cases, such implicit mechanisms can counteract the impact of explicit carbon pricing policies, for example, policies that subsidize fossil fuels.[10] Although robust carbon pricing is a key component in decarbonization efforts, it is but one part of a larger package of complementary policies[11] to reduce greenhouse gas emissions.[12] For example, the large-scale transformation of the power sector requires additional policies that support infrastructure development, market design, and low-carbon R&D.

## FINANCIAL DISCLOSURE OF CLIMATE-RELATED RISKS AND OPPORTUNITIES

A heightened focus on the need for transparent information on the financial implications of climate change is illustrated by a growing demand from lenders, insurers, and investors. Given the increased likelihood of financial disruption and stranded assets, climate change is moving up the agenda for investors as a material risk that companies must assess, publicly disclose, and manage in a comprehensive and consistent manner.

In 2015, the Financial Stability Board of the G20 Finance Ministers and Central Bank Governors, chaired by Bank of England Governor Mark Carney, commissioned the Task Force on Climate-related Financial Disclosures (TCFD or Task Force) with the objective of providing guidance on how to integrate climate risks and opportunities into mainstream financial reporting.[13] Composed of 32 private sector actors from across the G20's constituency, the TCFD represents a broad range of economic sectors and financial markets. Drawing on the expertise of its members, extensive stakeholder engagement, and existing climate-related disclosure regimes – such as CDP's work to institutionalize climate change into mainstream reporting – the Task Force designed a framework of recommendations to further understanding for stakeholders on climate risk exposure through carbon-related assets. The final recommendations were published in June of 2017.[14]

The foundation of the TCFD framework rests on the categorization of financial risks and opportunities that impact the private sector. While this topic has been extensively researched, it has yet to be standardized. The framework divides climate-related risks into two categories: (1) risks related to the physical impacts of climate change; and (2) risks related to the transition to a lower-carbon economy. The latter encompasses the extensive policy, legal, technology, and market changes that will likely manifest in a decarbonizing economy.

Under certain circumstances, these changes may pose material financial and reputational risks to organizations. The main types of risks and opportunities are described on the following page. While physical risks are a key factor to consider in determining the financial impact of climate change, this report focuses exclusively on the role carbon pricing can play in assessing transition risks and opportunities.

6 EDF and IETA, "Carbon Pricing: The Paris Agreement's Key Ingredient," April 2016.

7 Peter Fairley, States Are Using Social Cost of Carbon in Energy Decisions, Despite Trump's Opposition August 14, 2017.

8 World Bank, Ecofys and Vivid Economics. 2017. State and Trends of Carbon Pricing 2017 (November), by World Bank, Washington, DC.

9 High-Level Commission on Carbon Prices (World Bank), Report of the High-Level Commission on Carbon Prices, 2017.

10 Elizabeth Bast, Alex Doukas, Sam Pickard, Laurie van der Burg and Shelagh Whitley, "Empty promises: G20 subsidies to oil, gas and coal production," November 2015.

11 CPLC, *How can Carbon Prices and Policies be effectively aligned?*, November 2016.

12 CDP, "Carbon Pricing Pathways Toolkit: Navigating the Path to 2°C," September 2015.

13 The Taskforce on Climate-related Financial Disclosures, *Recommendations of the Task Force on Climate-related Financial Disclosures*, June 2017.

14 Ibid.

# CLIMATE-RELATED FINANCIAL RISKS

**Figure 1.**
Climate-related transition risks and financial impact[15]


1. Risks from **policy and legal** actions are expected to increase, as more policy is developed to mitigate GHG emissions and adapt to the impacts of climate change. For instance, there are already compulsory and voluntary carbon pricing mechanisms in use which aim to impact financial considerations.
2. Risks from the impact of low-carbon **technology** improvements and innovation can also have a significant potential impact on an organization. The process is described as "creative destruction," where new technologies and related services emerge and shift the economic rationale for old technologies deployed in the incumbent system.
3. Risks and opportunities from climate change for **markets** is increasingly seen through shifts in supply and demand for certain commodities, products, and services. The lower-carbon economy may also open-up new **market opportunities**, such as underwriting or financing climate-related green bonds and infrastructure.
4. Risks for organizational r**eputation** will rise from an increasing awareness of customers and/or community regarding climate-related actions.
5. Opportunities from organizational energy or **resource efficiency** measures create short-term operating cost savings for transport and production processes and indicate long- and medium-term financial benefits.
6. Opportunities are also realized from switching **energy sources** from fossil fuels to low-carbon alternatives such as wind, solar, biofuels, etc. Over the last two years, investment in clean energy has surpassed that of fossil fuels, from which significant savings have been made on annual energy costs.
7. Companies can benefit from developing new low-carbon **products and services** as a competitive advantage, emphasizing the reduction or avoidance of emissions.
8. Increased **adaptability**, which links to organizational profitability dependent heavily on suppliers and employees, is another category of opportunities. In specific sectors, insurance companies have opportunities to underwrite new assets (e.g. renewable energy technology installations).

15 Adapted from The Taskforce on Climate-related Financial Disclosures, *Recommendations of the Task Force on Climate-related Financial Disclosures*, June 2017.

"Climate change is increasingly a mainstream issue for investors, as the feedback loop between the policy framework and technological innovation – driving an irrevocable global energy transition away from fossil fuels towards renewable and clean energy sources – continues to intensify. The TCFD recommends that energy companies in particular acknowledge the reality of transition risk by running scenario analyses of potential future climate outcomes (including a 2°C scenario). In my view, central to any such scenario analysis should be gauging the impact of carbon pricing on company business models – over time capital will be re-allocated in accordance with carbon pricing signals."

— **Mark Lewis,** Head of Research, Carbon Tracker and Member of the TCFD

## INTERNAL CARBON PRICING

Internal carbon pricing has emerged in the corporate sector as a forward-looking metric that can be used to assess and manage carbon-related risks and opportunities arising from the transition to a low-carbon economy. Assigning a monetary value to the cost of carbon emissions helps companies monitor and adapt their strategies and financial planning to real-time and potential future shifts in external carbon markets.

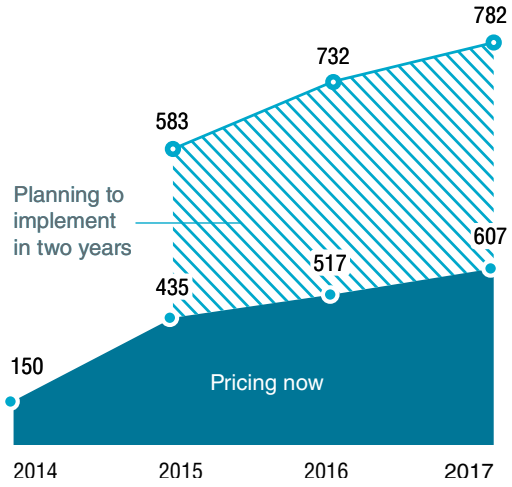
In many geographies, implicit carbon pricing signals may also arise from changing technological, regulatory and market dynamics – for example, energy efficiency standards and support for renewable energy, as well as shifts in supply and demand for low-carbon infrastructure, products and services. These factors, combined with policies, create a signal indicating the present and future cost of carbon. Leading companies have started to calculate and internalize this cost using an internal carbon price as a proxy for a broader set of transition risks.[16] [17]

Over the past few years, CDP has been tracking the growing trend of internal carbon pricing in the private sector. In 2017, nearly 1,400 companies disclosed to CDP their plans to implement or current practice of using an internal carbon price to manage climate-related risks and opportunities (see figure 2).[18] This includes more than 100 Fortune Global 500 companies with a total annual revenue of about USD 7 billion.

These companies, across all industries and geographies, have identified internal carbon pricing as an approach to building prudent buffers into their business models in preparation of a carbon-constrained future. Companies also disclosed to CDP that embedding the cost of carbon into CAPEX decisions, economic forecasts, and in some cases their operations, can help them better mitigate the risks and opportunities posed by existing or emerging carbon pricing regulations; prioritize energy efficiency; and drive investments in renewable energy purchases and other GHG emissions reduction activities.

For many organizations, the most significant impacts of these transition risks will emerge over time at scales of uncertain proportions. Therefore, the TCFD recommends that organizations use scenario analysis – a process of analyzing possible future events by considering alternative possible outcomes – as a tool "to assess potential business, strategic, and financial implications of climate-related risks and opportunities and disclose those, as appropriate, in their annual

**Figure 2. Growth of Internal Carbon Pricing**




16 For additional information, see: Ecofys, The Generation Foundation and CDP, *How-to guide to corporate internal carbon pricing – Four dimensions to best practice approaches, Consultation Draft*, September 2017. Prepared under the Carbon Pricing Unlocked partnership between the Generation Foundation and Ecofys in collaboration with CDP.

17 For additional information, see: World Bank, "Preparing for Carbon Pricing: Case Studies from Company Experience: Royal Dutch Shell, Rio Tinto, and Pacific Gas and Electric Company," January 2015. Partnership for Market Readiness, World Bank, Washington, DC.

18 CDP, Putting a price on carbon: Integrating climate risk into business planning, October 2017.

"MN is the third largest pension asset manager of the Netherlands with an AUM of 120 billion Euro. It is our fiduciary duty to ensure that the pensions of beneficiaries are not undermined by the serious risks that climate change presents to the risk/return of the portfolio and to financial stability more broadly. We believe that pension funds should work together to align portfolios with the goals of the Paris Agreement and that the Corridors has the potential to develop into a global metric to help us to do just this."

— **Gerald Cartigny,** Member of the Managing Board and CIO, MN

financial filings."[19] Scenario analysis helps organizations identify indicators to monitor changes in the external environment, enabling them to adapt their strategies and financial planning accordingly.

The TCFD specifically identifies internal carbon pricing as a key metric that can be used to assess climate- and energy transition-related risks, recommending disclosure around the assumptions made about how internal carbon prices and ranges would develop over time; whether prices apply to specific facilities or demand projections for fossil fuels; whether prices are applied to specific economic sectors or across the whole economy and in what regions; and whether a common internal carbon price or differentiated prices are used at multiple points in time. The rationale is to provide investors with a proper understanding of the reasonableness of assumptions made as an input for their risk assessment.[20]

Carbon pricing can be used as a forward-looking metric in scenario analysis to conduct and respond to risk assessments. The rationale of this approach is to improve the ability of investors and other interested actors to appropriately assess and price climate-related risks and opportunities. Existing models used to calculate scenarios in line with a 2°C pathway involve various assumptions related to the cost reductions of certain technologies. Many of those scenarios include techno-economic carbon price signals as a key proxy to model the complex explicit and implicit signals needed from low-carbon policies. **Carbon pricing thus has the potential to serve as a uniform, globally understood metric.**

Given the momentum generated around the Paris Agreement, in particular with respect to carbon pricing, a forecast for the range of prices necessary to drive the low carbon transition, such as the Carbon Pricing Corridors, will help bring more certainty to accelerate efforts around global emissions reductions. The range of the Corridors reflects regional differences, inherent uncertainties, and a variety of stakeholder perspectives on the needed prices based on inputs from markets actors, rather than one fixed forecasted price. This provides stakeholders with a set of prices for a wide range of uses and a reference guide/proxy that encompasses the multiple changes occurring in the transitioning market. Moreover, both investors and companies can use the Corridors to better understand the potential transition risks as carbon pricing evolves as a driving force toward a low-carbon economy.

The Task Force defines an **internal carbon price** as "an internally developed estimated cost of carbon emissions," which "can be used as a planning tool to help **identify revenue opportunities and risks,** as an incentive to **drive energy efficiencies** to reduce costs, and to **guide capital investment decisions**."[21]

19 The Taskforce on Climate-related Financial Disclosures, *Recommendations of the Task Force on Climate-related Financial Disclosures*, June 2017, page 25.

20 The Taskforce on Climate-related Financial Disclosures, *Recommendations of the Task Force on Climate-related Financial Disclosures*, June 2017.

21 The Taskforce on Climate-related Financial Disclosures, *Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures*, June 2017, page 79.

# 02 THE CORRIDORS INITIATIVE

"The Carbon Pricing Corridors project provides a better understanding of the key role that carbon pricing has to play in decarbonizing the power sector, as it is a signal for consumption, investment and operational decisions. It can provide useful insight regarding the opportunity and the existing gaps for each sector to engage in the transition."

— **Ignacio S. Galán,** Chairman and Chief Executive Officer, Iberdrola

## INITIATIVE PROCESS AND OBJECTIVE

In 2017, CDP and the We Mean Business Coalition launched the Carbon Pricing Corridors initiative with the aim of enabling large market players to define the carbon prices needed for industry to meet the Paris Agreement.

The Corridors were developed through an iterative inquiry with an expert Panel – a select group of leaders, primarily from the corporate and investment communities, alongside a handful of international experts. Throughout the inquiry process, panel members shared expectations of the range of investment-grade carbon-related price signals that would decarbonize the power and chemical sectors in the short- to medium-terms (2020, 2025, 2030 and 2035). The Corridors is distinct from similar initiatives and research efforts in that the process directly engages market actors to collect their insights and analyses of the price signals that will drive investment decisions in their companies.

Expert opinions were obtained via an inquiry process[22] requesting panel members respond to a small set of quantitative and qualitative questions and participate in a spoken interview. The results were collected and analyzed to determine an aggregate projection for the Corridor of carbon prices over time. The inquiry process also highlights the factors that panel members considered when developing their carbon price corridor projections – providing insight into the various price signals in the economy affecting the cost of carbon and varying degrees of investment certainty.

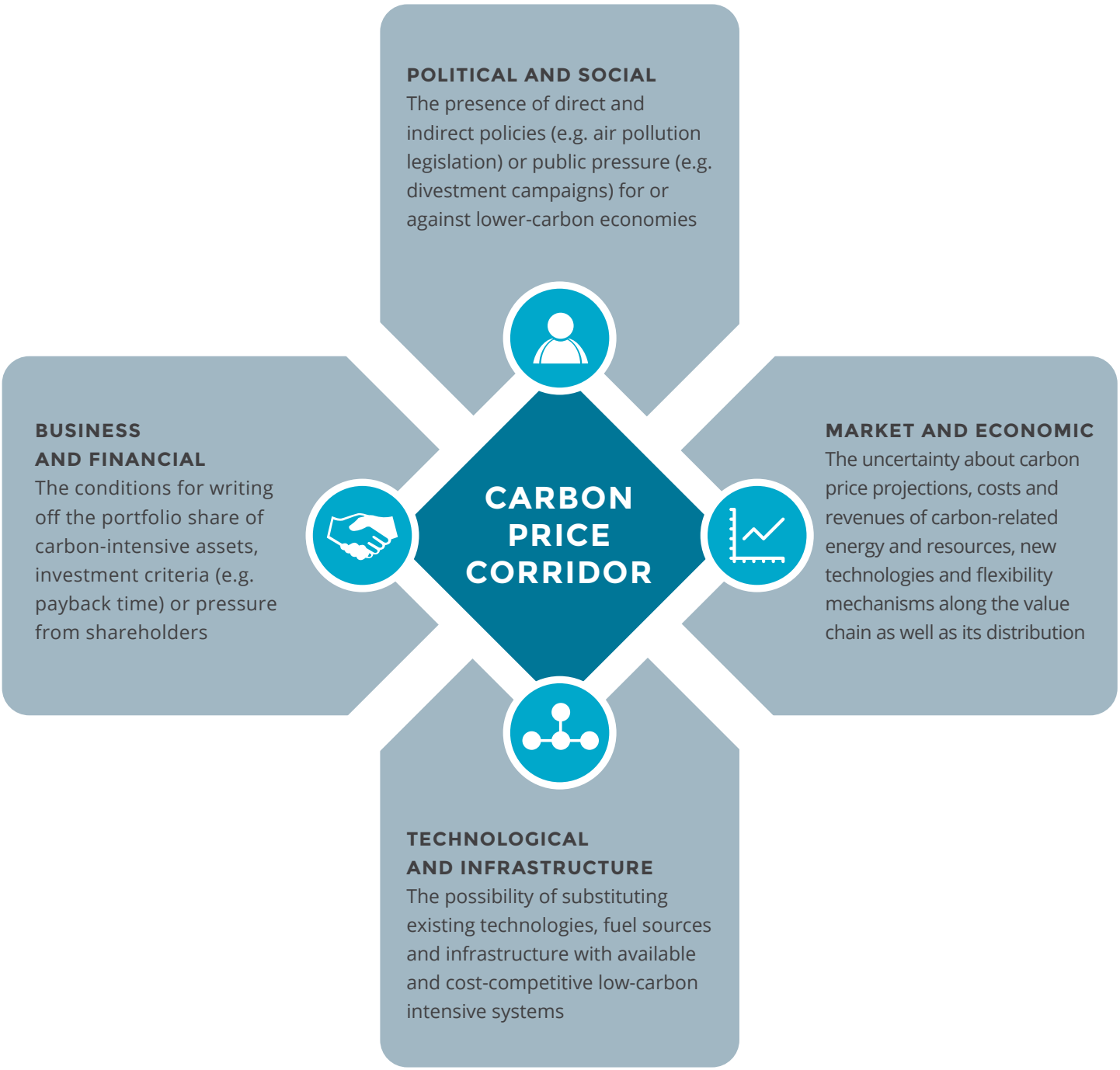
This report provides an updated corridor for the power sector and a new corridor for the chemical sector. The inquiry was designed to gather panel members' insights into:

- The carbon price needed to ensure the delivery of emissions reductions required for the power/chemical sectors to decarbonize in line with the Paris Agreement, differentiated by 5-year intervals (2020, 2025, 2030 and 2035),
- The likelihood of such prices materializing in those time periods, and
- The factors that influence projected carbon pricing levels.

Panel members were asked to comment on the importance of factors in four categories: political and social, market and economic, business and financial, and technological and infrastructure (see figure 3). For a comprehensive factors list, please see the Appendix.

22 The Corridors Initiative uses the Delphi Method which entails a group of experts who anonymously reply to questionnaires and subsequently receive feedback in the form of a statistical representation of the "group response," after which the process repeats itself. The goal is to reduce the range of responses and arrive at something closer to expert consensus. The Delphi Method has been widely adopted and is still in use today.

**Figure 3.** Factors considered when creating the Carbon Pricing Corridors



## HOW THE CORRIDORS CAN BE USED

The Corridors are carbon price signals for 2020, 2025, 2030 and 2035 that the Panel considers necessary to decarbonize the chemical/power sectors and meet the ambitions of the Paris Agreement. Which Corridor between 2020 and 2035 is most appropriate to use depends on the time frame of the decision.

The Carbon Pricing Corridors provide organizations with a tool for scenario analysis to meet the TCFD recommendations of assessing and disclosing implications of climate-related risks and opportunities.[23] The corridor represents a range of internal carbon price levels that can be used by the private sector to stress test against a 2°C scenario and consider the potential financial, strategic, and business impacts resulting from the Paris Agreement in their decisions. Policymakers can use the Corridors to assess the efficacy of explicit carbon pricing systems either under development or already in existence.

**Investors and the financial sector** can use the Corridors as a uniform metric to assess carbon-related transition risks and identify new revenue opportunities in their chemical and power-related portfolios.

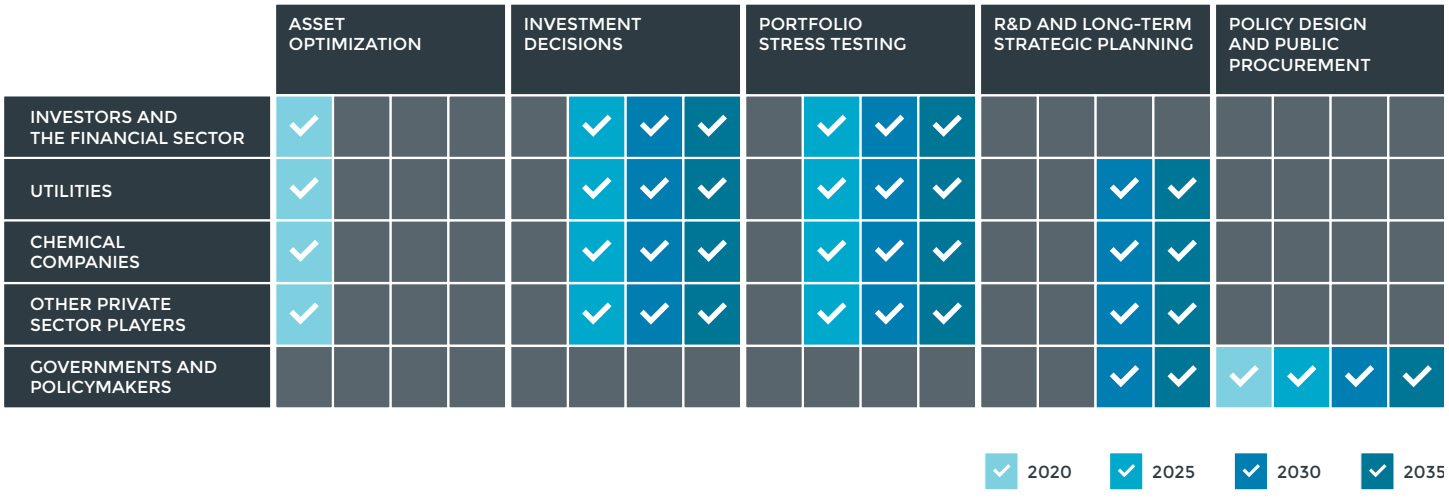
Investors and lenders may be indirectly exposed to a variety of carbon risks through their clients, particularly via loans or investments made to companies that are energy-intensive and/or rely on carbon-intensive inputs.[24] Applying the Corridors to the carbon footprint of investments in the chemical and power markets can help investors determine the financial robustness of their assets and debt in a decarbonizing world. This includes conducting materiality assessments of financed emissions and managing portfolios to minimize the risk of value loss. This application of the Corridors may also surface opportunities to develop new financial products and investment strategies that hedge against carbon-intensive assets and capitalize on low-carbon technologies.

Investors can also use the Corridors to assess the best and worst-case return on investment (ROI) and set appropriate hurdle rates to take climate-related risks or opportunities into account.

23 The Taskforce on Climate-related Financial Disclosures, *The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities*, June 2017.

24 The Taskforce on Climate-related Financial Disclosures, *Recommendations of the Task Force on Climate-related Financial Disclosures*, June 2017.

**Figure 4.** User Matrix: How different stakeholders can use the Carbon Pricing Corridors



"Carbon pricing is a critical tool in the global fight against climate change. A standardized mechanism to price carbon will enable businesses to recognize the cost of greenhouse gas emissions from their business activities, and thus catalyze industry-wide decarbonization. Carbon Pricing Corridors provides financial institutions like YES BANK, who are committed to climate action, an opportunity to integrate carbon pricing into investment decisions, optimize operational performance and mobilize finance towards a low-carbon future."

— **Rana Kapoor,** Managing Director and CEO, YES BANK

Furthermore, for investors that actively engage with their investee companies, the Corridors can be used to sense check and benchmark the carbon price level(s) being used in these companies' risk management approaches. For example, do the assumptions behind Company A's internal carbon price(s) match or differ from that of its peers or even that applied by the investor itself? Investors can also consider how the carbon price(s) are being applied. Are they used to assess current risk (i.e. the carbon footprint) and/or used to actively prepare for the future (i.e. stress testing assets and investments against various scenarios)?

**Companies** can use the Corridors to assess their potential additional carbon costs and how they may affect the competitive position of their portfolio units in a changing power and chemical market landscape. This would allow them to make informed decisions on optimizing the deployment strategy of their current assets in the short-term and diversify their portfolio in the medium- and long-term.

The lower end of the Corridors can be used to establish, or benchmark, existing internal carbon price levels and assumptions – at a bare minimum, allowing companies to hedge against regulation and other carbon-related transition risks that its industry peers are also monitoring closely. For more ambitious companies, the higher end of the Corridors can be used for scenario analysis of new investments, long-term strategic planning, or R&D decisions, testing the robustness of these decisions against the ROI requirements and other criteria assuming rapid decarbonization or even a 2°C scenario.

**The private sector more broadly** can use the power sector Corridor to assess the potential direct and indirect impact of additional carbon costs along the energy value chain. Increasing energy supply costs will shift among market players – directly impacting the cost structure of energy-intensive industries and enabling new revenue streams for intermediating energy services such as flexible demand response or energy efficiency measures. Implementing carbon pricing as one of the tools to identify and participate in new business models can help strategic decision-making accordingly.

The Corridors could also be utilized by companies in other sectors seeking to decrease the emissions intensity of the power they use in their operations and value chains or simply procure energy from alternative technologies. The Corridors metric can be used to improve the business case for these investments.

**Governments and policymakers** can use the Corridors as a basis to design new, or reform existing, policies to provide the carbon price signals needed for low-carbon investments. In addition, policymakers can use the sector-specific Corridors as an internal carbon price to guide public procurement decisions related to energy and materials, as well as in the assessment of various policy proposals.

This could help harmonize mitigation incentives across government agencies, rationalize government investments across competing objectives, and catalyze a broader discussion about effective policy design within the private and public sectors.[25] We summarize this in the user matrix in Figure 4, indicating how the 2020, 2025, 2030 and 2035 Corridors established in this report can be used. Examples of questions these different groups of stakeholders can address with the Corridors are provided on the next page.

25 Adele Morris, "Why the federal government should shadow price carbon," July 13, 2015.

# EXAMPLES OF QUESTIONS KEY STAKEHOLDERS COULD ANSWER WITH THE CORRIDORS

### ASSET OPTIMIZATION

How can I, as a chemical/power company, optimize the use of my current assets given the Corridors and the prevailing explicit carbon price in the jurisdictions I am active in?

### INVESTMENT DECISIONS

Would my investments still meet ROI requirements if I apply short- to mid-term Paris compatible Carbon Pricing Corridors to the ROI calculations and what does this mean for the allocation of investments in my company?

### PORTFOLIO RISK ASSESSMENTS

Is my portfolio of assets or loans financially robust when applying the Corridors to my financed emissions and how can I optimize my portfolio?

### R&D DECISIONS

How robust are my R&D and market development choices when applying long-term Paris compatible Carbon Pricing Corridors?

### PUBLIC PROCUREMENT

What level of carbon price should I use in public procurement procedures to ensure the energy and materials I purchase help us to achieve the goals embedded in the Paris Agreement?

### POLICY DESIGN

How can I design policy so that they yield the Carbon Pricing Corridors required to place the chemical/power sectors on a Paris compatible trajectory?

"To succeed in establishing an effective signal towards sustainable investments and emissions reduction measures, Carbon Pricing Corridors are key in setting ambitious and incremental targets as a roadmap for 2020, 2025, 2030 and 2035. These corridors can be used by companies, investors and policymakers to help manage climate risk and to actively shift investments to the growing clean economy – Acciona will be including them in our own business planning going forward."

— **José Manuel Entrecanales Domecq,** Chairman and CEO, ACCIONA

# 03 THE CORRIDORS: THE CHEMICAL SECTOR

## CHEMICAL SECTOR – FEEDSTOCK FOR THE FUTURE

The revenue of the global chemical industry totaled USD 5.2 trillion in 2016.[26] As the industry sector with the largest final energy consumption (28%), not to mention a significant long-term projected increase in product demand,[27] the chemical sector has a critical role to play in the economy-wide low-carbon transition.

In 2014, the chemical and petrochemical industry accounted for almost one fifth of all direct industrial carbon dioxide emissions.[28] The sector's greenhouse gas emissions predominantly result from fuel combustion for energy in chemical processes and process emissions from the use of fossil feedstocks, representing 40% and 60% of energy usage for petrochemical products respectively.[29]

As such, emissions reduction potential in large part depends on the type of energy source and feedstocks used in the chemical manufacturing process. The IEA projects that technologies in development to decarbonize industrial processes pose to reduce carbon emissions by 18% in a 2°C scenario and 36% in a below 2°C scenario.[30]

To achieve the levels of decarbonization outlined by the IEA in a 2°C scenario and below 2°C scenario, bio-based raw materials and process routes currently provide the most promising pathways. Main levers for CO2 emissions reductions in a 2°C scenario by 2025 are process energy efficiency (78%), the switch to lighter fuels and feedstock (18%), and improved plastics recycling (5%). Taking these measures into account, energy use and direct CO2 emissions in the chemical industry can only rise by a yearly average of 3.6% and 2.8% respectively through 2025.[31]

Important enabling factors to achieve a below 2°C scenario include a more widespread and rapid deployment of carbon capture and storage (CCS) technologies, and technological combinations that facilitate negative emissions, for example, the use of bio-based feedstocks in combination with CCS (BECCS).

BOX 1

### Catalyst for Change

A CDP report analyzing the preparedness of chemical companies for the low-carbon transition reports high levels of carbon risk for the sector in the medium- to long-term. The breakthrough technologies required to mitigate these risks are expected to be "5-10 years away with current process innovation based on incremental improvements."[32] The report also notes the global chemical industry has a high level of R&D expenditure as a proportion of sales compared to other industry groups – around five times higher. For example, R&D makes up 7.6% and 7% of expenditure respectively for Sumitomo and DuPont. AkzoNobel and DSM report that 80 to 100% of its R&D expenditure goes towards low-carbon products.

26 Statista, "Total revenue of the global chemical industry from 2002 to 2016," 2018.

27 U.S. Energy Information Administration, *International Energy Outlook 2016*, May 2016.

28 IEA, *Tracking Clean Energy Progress 2017*, 2017.

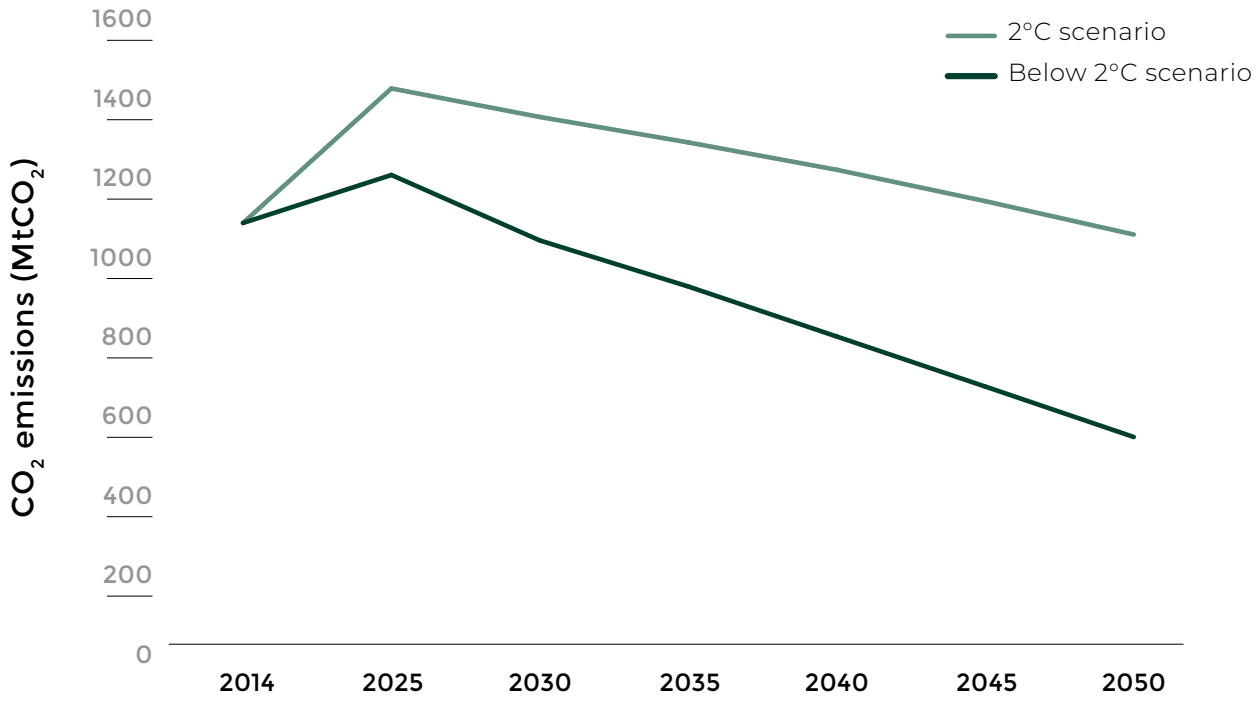
29 CDP, *Catalyst for change: Which chemical companies are prepared for the low carbon transition?*, October 2017.

30 IEA, *Energy Technology Perspectives 2017*, 2017.

31 IEA, *Tracking Clean Energy Progress 2017*, 2017.

32 CDP, *Catalyst for change: Which chemical companies are prepared for the low carbon transition?*, October 2017.

**Figure 5. CO2 emission pathways for the chemical and petrochemical sector**




To illustrate, when moving from a 2°C scenario to a below 2°C scenario, the projected carbon capture in the industry moves from 1.5 Gt CO¬2 to 3.4 Gt CO2, a much stronger increase compared to power sector CCS. Looking at chemicals specifically, CCS is only applied to 60% of the ammonia production and 48% of the methanol production in a 2°C scenario, with shifts to 93% and 100% respectively in 2060. This difference is even more pronounced for high-value chemicals (HVCs), which go from hardly applying CCS in a 2°C scenario, to 91% in a below 2°C scenario, since CCS is less cost-effective for HVCs than for methanol and ammonia.[33]

Other levers, such as recycling, also play a strong role in a below 2°C scenario. Global collection of waste plastics for recycling improves from 10% in 2014 to 41% by 2060 in the below 2°C scenario. This results in significant cumulative reductions in primary chemical demand for plastics production.[34]

Figure 5 details the emissions reduction pathway for the chemical and petrochemical sector in a 2°C and below 2°C scenario. In both scenarios, CO2 emissions peak around 2025, with just a slight lag in a 2°C scenario. However, the 2°C scenario increases by more than 200 million metric tonnes before this peak and barely gets back down to its starting point of about 1000 million metric tonnes by 2050. In comparison, the below 2°C scenario increases by less than 100 million metric tonnes before peaking and in fact decreases to 600 million metric tonnes by 2050, with the use of carbon capture technology.

In contrast to the decarbonization pathway for the power sector, the IEA does not expect complete emissions reductions in the chemical sector by 2050. This can be

33 IEA, *Energy Technology Perspectives 2017*, 2017.

34 Ibid.

mainly attributed to the fact that the chemical sector does not currently have emissions reduction technologies at the level of viability needed to decarbonize by 2050. Moreover, decarbonization of the chemical sector in part rests on that of the power sector, as renewable electricity is expected to start replacing fossil fuels in chemical production processes towards the end of the forecast period.

To date, chemical companies have largely made short-term investments in energy efficiency measures at the plant- and facility-levels and increased reaction yields, the gains of which have largely been achieved.[35] Medium- to long-term reductions will rely on the development of innovative technologies. Given that 95% of manufactured products rely on chemicals products,[36] the sector can contribute to the decarbonization of the entire value chain via the development of low-carbon products. At the same time, it is largely dependent on the power sector for the decarbonization of its electricity as mentioned above.

Renewable energy has the potential to reduce emissions by substituting emissions-intensive feedstock and fuels.[37] An unexploited 32% increase in the direct use of renewable heat by 2025 is projected as needed to meet a 2°C scenario. For reference, between 2010 and 2014, biomass, solar thermal, and geothermal consumption increased by 8%.[38] Feedstock from renewable bio-based sources, including biomass waste, are also crucial to achieving a 2°C scenario. The trend towards the switch to lighter feedstocks restricted energy consumption and direct CO2 emission growth below 3% between 2000 and 2014.[39]

However, the ambition levels as seen in the 2°C scenario and below 2°C scenario may be particularly difficult to achieve if the cost of emitting carbon remains insignificant.[40] Although some companies are developing alternatives to existing products and processes to reduce carbon emissions, this development is often not a direct result of a carbon price incentive. For example, the availability of cheap fossil fuels may disincentivize companies from developing lower-carbon technologies to directly incorporate into chemical processes. Therefore, while recognizing that higher carbon prices are needed for the sector, other policy instruments must also be deployed.

Large-scale adoption of bio-feedstocks is limited by an unsustainable supply and other environmental considerations, such as biodiversity impacts and agricultural competition.[41] Regardless of the extent of this adoption, however, emissions reductions are not adequate to meet the Paris Agreement. Current modelling therefore indicates that complementary technologies such as CCS[42] or carbon capture and utilization (CCU, in which carbon itself is captured and recycled as feedstock)[43] will need to be employed during or after the manufacturing process in order to decarbonize the chemical sector in the time necessary.

35 CDP, *Catalyst for change: Which chemical companies are prepared for the low carbon transition?*, October 2017.

36 Ibid.

37 National Research Council of the National Academies, *Sustainability in the Chemical Industry: Grand Challenges and Research Needs*, 2006.

38 IEA, *Tracking Clean Energy Progress 2017*, 2017.

39 Ibid.

40 Will Nichols, "Strong carbon price can drive CCS success, says TCM chief," businessGreen, January 26, 2015.

41 CDP, *Catalyst for change: Which chemical companies are prepared for the low carbon transition?*, October 2017.

42 For additional information, see: Carbon Counts, *CCS Roadmap for Industry: High-purity CO2 sources, September 2*, 2010.

43 For additional information, see: CO2 Sciences and CO2 Initiative, *Global Roadmap for Implementing CO2 Utilization*, November 2016.

## THE RESULTING CORRIDOR

Figure 6 shows what panel members deem to be the necessary price levels by 2020, 2025, 2030 and 2035 to decarbonize the chemical sector in line with the Paris Agreement. Fifty percent of the Panel's responses fall within the 'majority corridor' indicated by the darker green. The light green represents the full sample of panelist responses.

According to most panel members, the needed carbon price corridor for 2020 runs from USD 30-50/tonne. This forecasted corridor increases to USD 36-71/tonne in 2025; to USD 40-100/tonne for 2030; and to USD 50-100/tonne for 2035.

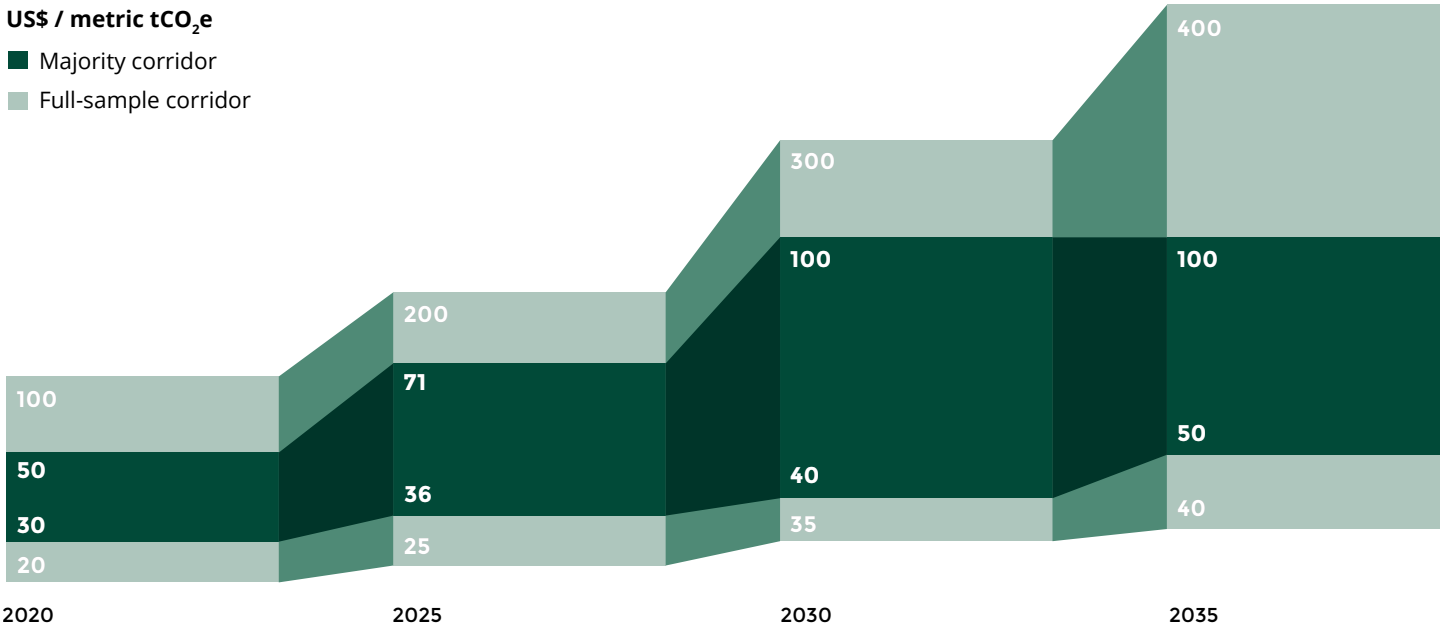
The corridor range widens over time, aligning with increased levels of uncertainty regarding the development of several political, technological and economic factors as panel members forecast into the future. The high end of the full sample Corridor represents an outlier perspective among the Panel projections. The majority corridor steadily increases across each period, until stabilizing at USD 100 in 2030-2035. This demonstrates a consensus, among a diverse group of panelists, that the carbon price signal needs to strengthen over time.

Interestingly, the lower range of the Corridor is notably higher than existing explicit carbon price levels imposed by government regulation, demonstrating a consensus view among the Panel that higher carbon price signals are needed in the chemical industry than are currently observed in existing markets. The following factors section will further explore the variety of factors which influenced the carbon price levels forecasted by panel members.

The geographical coverage of the Corridors Panel surveyed includes 18 G20 countries, excluding Argentina and Indonesia (see figure 7). The heterogeneous group (including commodity, diversified, and specialty chemical companies) represented more than USD 180 billion in market cap in 2016,[44] and thousands of chemical products among them.

44 Accessed on Bloomberg Terminal, April 13, 2018.

**Figure 6.** Resulting Chemical Corridor from 2018 Inquiry




**Note:** upper range of full-sample corridor is not shown to scale

**Figure 7.** Corridor Inquiry G20 country coverage (chemical sector)


## IMPLICIT AND EXPLICIT FACTORS INFLUENCING THE CORRIDORS

Panel members considered a wide range of factors that may influence the carbon price levels needed to decarbonize the chemical sector in line with the Paris Agreement. These factors may be direct or indirect costs or incentives associated with transitioning to a low-carbon economy. As highlighted before, factors were divided into four categories: political and social, business and financial, market and economic, and finally technological and infrastructure.

Various **political and social** factors were mentioned as impacting the carbon price level needed to decarbonize the chemical sector.

Explicit carbon pricing regulations (ETS or tax) were identified as key factors influencing the needed carbon price levels. In markets without policies, panelists had low expectations, or were uncertain, regarding their future development. In markets where such policies do exist, several panelists noted that the price signals are too weak (low) to incentivize the emissions reductions needed to stay aligned with a 2°C scenario. In lieu of strong external policies driving reductions in the power and industrial sectors, the carbon price signal for the chemical sector would need to be notably higher in the longer-term. Panelists also highlighted the need for global convergence of carbon markets, or mitigation measures, to avoid carbon leakage over time.

Most panelists noted that carbon pricing regulation alone is not sufficient to incentivize innovation in the chemical industry at the scale needed for a 2°C scenario. Specifically, some panelists mentioned the critical role

"Braskem is committed to be part of the solution of sustainable development, and especially on climate change. Since 2008, Braskem has reduced the intensity of its greenhouse gas emissions by 20%. But more important than that, is Braskem's investment in the "chemistry of the future." Braskem strongly believes that bio-based products will make the difference. The carbon footprint of these products means concrete contribution to climate change mitigation. Investing in people's engagement and development as well as in Innovation and Technology development is crucial for the expected low-carbon future. For that, carbon pricing could be an important tool to support further development."

— **Carla Barretto,** Member of the Board, Braskem

of additional support policies to reduce the upfront costs of R&D – such as subsidies or tax breaks related to the development of low-carbon technologies. Such government incentives would reduce the carbon price level needed and vice versa.

Fossil fuel subsidies were noted as a policy factor that increases the cost of low-carbon energy sources for production and thus, drives up needed carbon price levels. It was further noted that policies incentivizing emissions reductions throughout the chemicals value chain would decrease the carbon price level needed for the sector – for example, the Best Available Techniques reference documents under the Industrial Emissions Directive and the IPPC Directive in the EU, which outline the required standards of manufacturing equipment in all industries.[45]

As the chemical industry has historically been pressured to improve the environmental and public health impacts of its production footprint and product handprint, some companies have embedded this responsibility into their business strategies. In such cases, this socio-political pressure has already incentivized emissions reductions and diminished the needed carbon price signal.

There was consensus among the Panel that **technology and infrastructure** factors significantly impact the carbon price levels needed to achieve a 2°C scenario in the chemical industry. Several panelists consider technological innovation as a critical enabler of process emissions reductions. This includes the integration of lower-carbon fuels and feedstocks, and the capturing and recycling of process emissions. Some panelists note the lack of commercially viable technologies as a factor that increases the needed carbon price signal to drive meaningful decarbonization. Others still expressed uncertainty regarding the capacity of future technologies to reduce emissions.

Moreover, many of these technologies may require new or updated infrastructure, such as CO2 pipelines for CCS or the re-use of alternative feedstocks, significantly increasing the cost of employing low-carbon technologies, and ultimately driving up the carbon price level needed to justify such investments.

The consideration of **market and economic** factors varied among panelists, depending on readily available resources in their market(s) of operation. Developments in the underlying energy market impact the chemical sector's ability to reduce emissions. The availability and cost of fossil fuel-based vs. low-carbon energy sources impact the carbon price signal needed to trigger the shift to consuming lower-carbon energy. Companies operating in robust renewable energy markets will require a lower carbon price signal than those operating in a market with cheap fossil-fuel based energy.

45 European Commission, "Reference Document on Best Available Techniques in the Ceramic Manufacturing Industry," August 2007.

Interestingly, market factors affected panelists' overall emissions reduction approaches and thus, their carbon price corridor projections. For example, companies located in markets with rich biomass resources, which can be used to create low-carbon energy and feedstock inputs, identified carbon price signals needed to drive a bio-based strategy. On the other hand, companies with access to burgeoning renewable energy markets primarily identified carbon price signals needed to make this energy switch.

Uncertainty regarding the future of the chemicals market and demand for manufactured products was also mentioned as a factor.

Several of the **business and financial** factors mentioned involved the expectations of investors and customers. Increased investor engagement related to climate-related risk management was noted by multiple panel members. Companies attributed this recent surge of interest to the work of the Task Force on Climate-related Financial Disclosures and the Paris Agreement. However, some panelists also reported that this interest is not yet strong enough to influence business strategy. Panel members also noted a shift in customer demand for lower-carbon products and processes, but stated that this demand too is not yet high enough to influence strategy and thus has not influenced the projected carbon price levels.

Corporate governance and culture emerged as a factor that impacted panelists' carbon pricing corridors. For a few companies, environmental and social responsibility has been embedded into the corporate culture and business processes for years. This has manifested in ambitious emissions reductions strategies and/or the development of low-carbon products. On the other hand, companies exclusively focused on climate risk mitigation identified a lack of financial incentives as a factor driving up the carbon price level needed for their company.

BOX 2

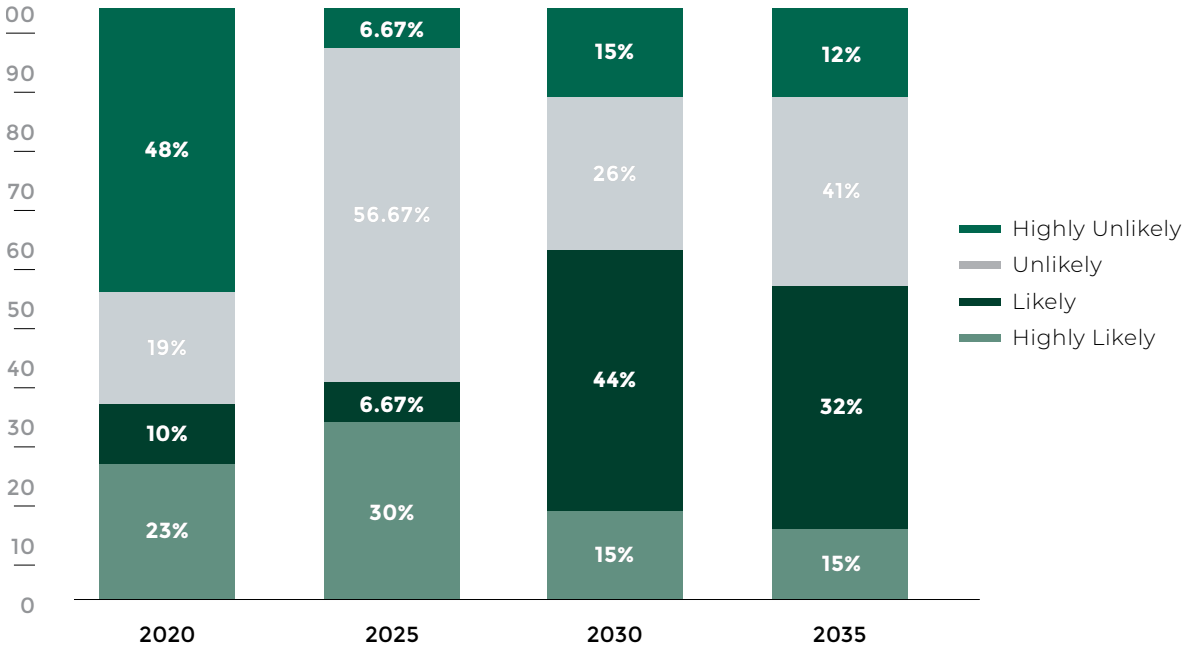
## Competitiveness Concerns in the Chemical Sector

Carbon pricing is one of the most efficient and effective policy mechanisms for driving innovation and increasing the competitiveness of low-carbon products and processes. However, without a global carbon pricing system or linked set of markets, companies subject to pricing fear a reduction of economic competitiveness against companies operating in unregulated countries. This unintended impact may result in "carbon leakage," where a company moves its operations to a non-pricing country. Competitiveness concerns can largely be addressed through well-designed policies incentivizing low-carbon investment and the removal of subsidies or other incentives for high-emitting activities.[46] A recent paper highlights consumption-based carbon pricing, in which consuming entities, rather than just the producing entities, bear the costs of the carbon emissions associated with the product.[47]

46 Carbon Pricing Leadership Coalition, *What is the Impact of Carbon Pricing on Competitiveness?*, June 2016.

47 Carbon Pricing Leadership Coalition, *How can consumption-based carbon pricing address carbon leakage and competitiveness concerns?*, April 2018.

**Figure 8.** Likelihood of the needed carbon price materializing in the market for the chemical sector




## ARE THESE CARBON PRICES LIKELY?

Panel members were asked to consider the likelihood of their projections materializing as explicit carbon prices in their markets in the 2020, 2025, 2030 and 2035-time periods. Figure 8 below summarizes the percentage likelihood of carbon prices materializing based on the total responses in each relevant period.

More than half of panelist responses in each period do not anticipate their projected price to materialize (answering "unlikely" or "highly unlikely"). However, the Panel demonstrated optimism for later time periods as the likely and highly likely categories grow from 33% to 37% between 2020 and 2025, to 41% in 2030, and 47% in 2035. Moreover, the percentage of projected price levels deemed highly unlikely drop dramatically from 2020 to 2025, from 48% to 7%.

Individual countries did not see much variation in the expected likelihood for needed prices to materialize among time periods. This is significant considering that most panelists acknowledged the need for stronger external price signals to transition to a low-carbon economy. In lieu of explicit carbon pricing providing this incentive, other implicit mechanisms will need to fill this gap.

## THE STATE OF INTERNAL CARBON PRICING IN THE CHEMICAL SECTOR

Fifteen percent of chemical companies that respond to CDP's internal carbon pricing question reported using an internal carbon price, at an average price of USD 42.15/ tonne of CO2e. An additional sixteen percent reported plans to implement one within two years. In contrast, the average price reported by all companies using an internal carbon price is approximately USD 30/tonne of CO2e, indicating that chemical companies may perceive a heightened risk of regulation as a high-emitting industry.

Furthermore, most of the companies that disclose a carbon price level apply a static price to their future investments – meaning that the internal carbon price is not expected to evolve, or increase, in the medium- to long-term. In some cases, companies have included this expectation into their strategic planning upfront with a higher static price. However, for others, it is possible that companies may be failing to properly plan for the long-term carbon risks associated with future capital investments, particularly given the long ROI period for certain large infrastructure assets in the sector.

# 04 THE CORRIDORS: THE POWER SECTOR

## POWER SECTOR – AT THE HEART OF THE LOW-CARBON TRANSITION

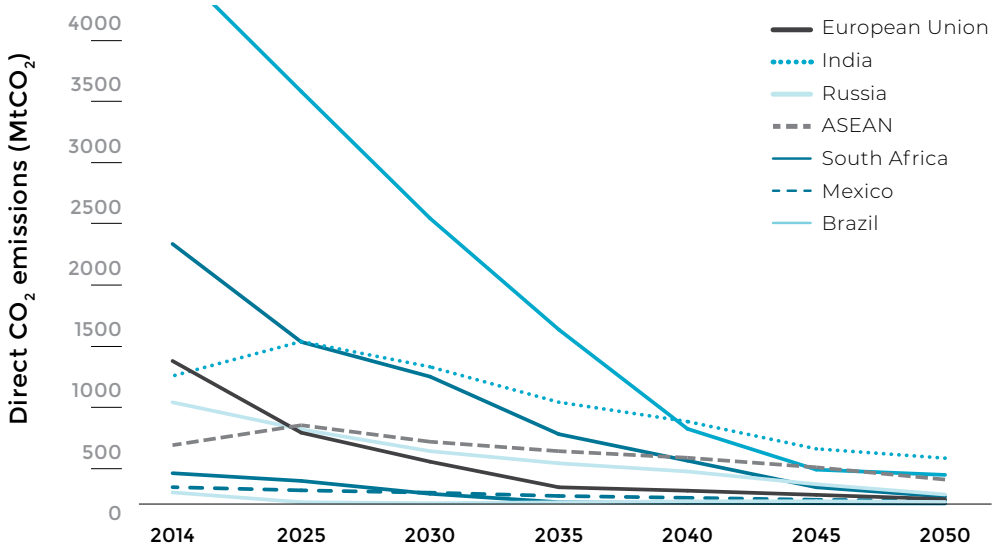
Arguably, climate change-related risks and opportunities are most real and direct for the power sector. Not only does the electricity generation sector contribute to around 25% of annual global greenhouse gas emissions, but it is also a sector where revenue generation has for decades been dominated by fossil fuel combustion processes resulting in GHG emissions. The potential for decarbonization of the power sector is huge with multiple low-carbon generation technologies available as well as advanced electricity infrastructure and storage technologies.

Decarbonization of the power sector also enables sectors consuming electricity to reduce their emissions. The electrification of transportation and heating will also create significant carbon reductions across the economy. This puts the power sector at the heart of the low-carbon transition and underlines the importance of having carbon price signals that can deliver on the ambitions of the Paris Agreement.

Low-carbon scenarios for the electricity sector suggest therefore that CO2 emission pathways for power generation, as opposed to certain other sectors, need to be nearly 100% decarbonized globally by 2050 to keep the average temperature rise below 2°C as shown in figure 9.[48] To further reach a 1.5°C target, emissions would need to be bound from the atmosphere through reforestation or innovative technologies such as bio-energy with carbon capture and storage (BECCS). The disruptive transformation of the power sector requires investments at scale that avoid locking in carbon-intensive technologies, a phase-out of fossil-based electricity generation, such as an early retirement of coal capacity or retrofits with carbon capture and storage (CCS), and a quick ramp-up of carbon-free technologies. This will go hand in hand with radical new designs of the electricity market reflecting the increasing importance of electricity storage and generation capacity.

The role of explicit and implicit carbon pricing in this transformation is complex, particularly in view of the different regulatory settings

**Figure 9.** CO2 emission pathways for the power sector by region in a 2°C scenario




48 IEA, *Energy Technology Perspectives 2017*, 2017.

"Based on what we know today, a sustainable energy future is defined by four products: renewables, energy storage, demand response & efficiency, and fast-start natural gas. Carbon pricing is a tool for supporting the business case behind investments in clean energy – but is not a panacea for large-scale infrastructure deployment. Pro-infrastructure financing policies, and market mechanisms, such as a Forward Clean Energy Market, can unlock competition towards securing sustained investments in clean energy, at the lowest costs to consumers. NRG has committed to science-based targets for reducing CO2 emissions from the company's portfolio, reflective of the fact that by 2050, the entire US economy must emit less carbon than today's power sector."

— **Bruno Sarda,** VP of Sustainability, NRG Energy

for the power sector across the world, but is one of the tools that can play a key role in this transformation. It should not be viewed as a one-size-fits-all policy solution or tool, however, as the structure of a specific electricity market will play a critical role in when and how a carbon price will work; understanding this will be vital to driving the transformation of the sector.

The latest analysis suggests that despite the progress the sector has made in comparison to others in the energy sector more broadly,[49] the pace of decarbonization in the power sector is not fast enough. The 2017 CDP utility analysis shows that in Europe, of the 14 major utilities – representing half of the EU electricity generation – only three are on a pathway to stay within their implied carbon budgets that help keep the average global temperature rise below 2°C.[50] The progress on CCS has been minimal as other low-carbon technologies are more cost-competitive, and CCS may not become commercially available in time to contribute to effective decarbonization if carbon prices remain low.

At the same time, some utilities have expanded their renewable capacity to diversify their portfolio, with the renewable generation capacity for these 14 utilities having grown from 25% in 2010 to 32% in 2016. However, much more progress is needed to fully decarbonize the sector and some utilities will need to retire their fossil

BOX 3

### Charged or Static: Which European electric utilities are prepared for a low carbon transition?

CDP's 2017 study on European electric utilities shows the impact of carbon prices on a utility's bottom line. The assessment highlights that relatively low carbon price levels in the European Union Emissions Trading System (EU ETS) can already cause significant impacts on earnings, with EBITDA losses between 0.3%-13.7% under a carbon price of €7.7/tCO2e in 2015. Utilities with a high share of fossil fuel generation assets experienced the highest losses. This impact is expected to become more profound in the future as the EU ETS was recently reformed with new measures to increase the carbon price. To illustrate this effect, carbon costs could rise to 38% of the EBITDA for fossil fuel-intensive utilities under a price of €30/t$CO_2$e, posing significant transition risks. A robust carbon price signal in this sense is powerful enough to drive shifts in investments and strategies in advance, driving fuel switching.

49 U.S. Energy Information Administration, "Carbon intensity of energy use is lowest in U.S. industrial and electric power sectors," May 2017.

50 CDP, Catalyst for change: *Which chemical companies are prepared for the low carbon transition?*, October 2017.

fuel assets before their technical lifetime is complete. Utilities and investors will need to decide on how to mitigate, transfer, accept, or control the risks related to the accelerated retirement of existing fossil fuel assets and associated valuation write-downs.

Higher carbon prices could substantially affect the profitability of utilities with many fossil fuel assets as demonstrated in CDP's latest sectoral report (see box 3).[51] Carbon price signals can have a significant impact on decarbonizing the power sector. The carbon price floor in the UK was for example a key driver in achieving Great Britain's first day without coal-fired electricity since the first industrial revolution.[52]

## THE RESULTING CORRIDOR

Figure 10 shows what panel members deem to be the necessary price levels by 2020, 2025, 2030 and 2035 to decarbonize the power sector in line with the Paris Agreement. Fifty percent of the Panel's responses fall within the 'majority corridor' indicated by the darker blue. The light blue represents the full sample of panelist responses.

According to most panel members, the needed carbon price corridor for 2020 runs from USD 24-36/tonne. This forecasted corridor increases to USD 30-58/tonne in 2025; to USD 30-100/tonne for 2030; and to USD 38-100/tonne for 2035.

Compared to the 2017 results, the bottom price level of the majority Corridor remained the same while the top saw a marginal decrease from USD 39-36/tonne in 2020 and USD 60-58/tonne in 2025. This year's power sector corridor includes projections out to 2035. While the full sample Corridor shows an increase in price level to USD 120 for this period, the majority Corridor remains steady at USD 100.

Interestingly, the bottom range of the majority corridor remains around USD ~30/tonne from 2025 onwards. This can partially be explained by the expectation that the levelized cost of renewable energy sources will continue to decrease; therefore, a lower carbon price will be needed to make renewable energy competitive with fossil fuel generation.

The lower end of the Corridors is still well above the current explicit carbon prices in most jurisdictions, highlighting a consensus view by panel members that higher prices than currently observed are needed. The following factors section will further explore the variety of factors which influenced the carbon price levels forecasted by panel members.

51 Ibid.

52 Georgia Brown, "British power generation achieves first ever coal-free day," April 21, 2017.

**Figure 10.** Resulting Power Corridor from 2018 Inquiry

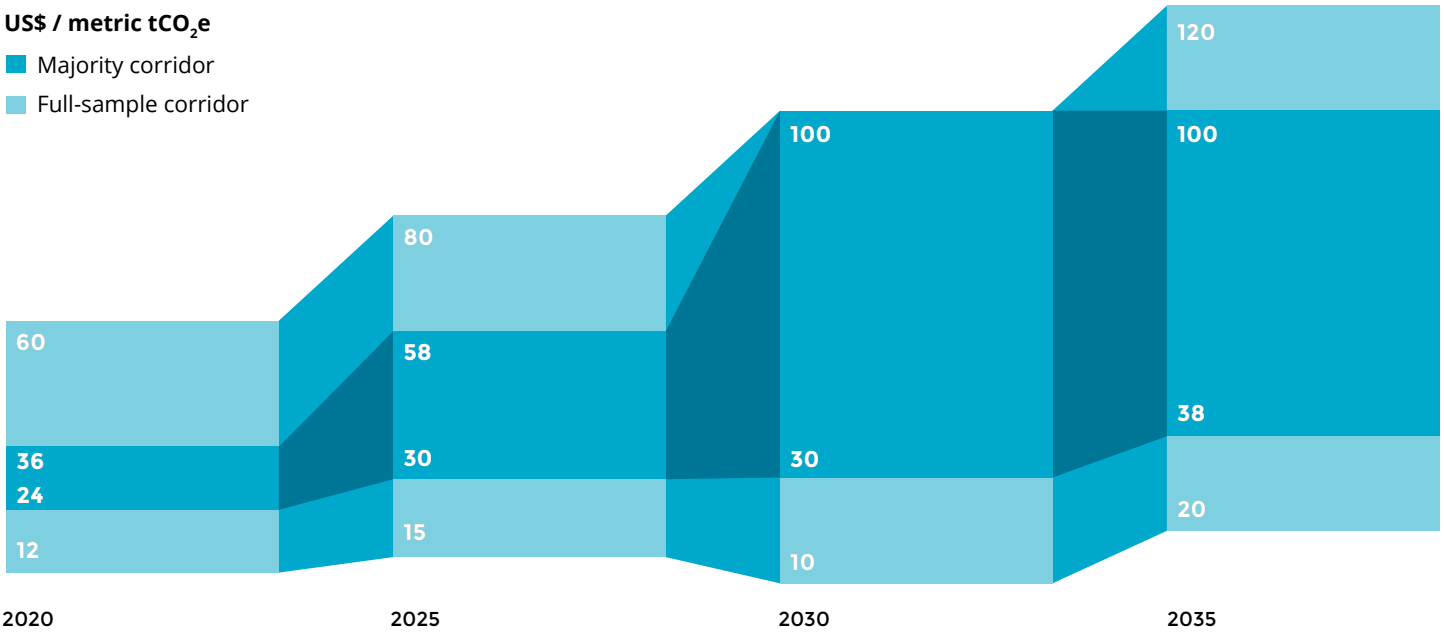


**Figure 11.** Corridor Inquiry G20 country coverage (power sector)


The geographical coverage of the Corridors Panel surveyed includes 15 G20 countries, excluding Argentina, Indonesia, Japan, Turkey, and Saudi Arabia (see figure 11). The group of utility companies represented more than USD 120 billion in market cap in 2017,[53] and the expert opinions of industry investors and research experts.

## IMPLICIT AND EXPLICIT FACTORS INFLUENCING THE CORRIDORS

Panel members considered a wide range of factors that may influence the carbon price levels needed to decarbonize the power sector in line with the Paris Agreement. These factors may be direct or indirect costs or incentives associated with transitioning to a zero-carbon power sector. As highlighted before, factors were divided into four categories: political and social, business and financial, market and economic, and finally technological and infrastructure factors.

Panelist responses clearly indicated the complex and diverse regulatory settings for the evolving electricity markets globally. **Political and social** factors were considered an important set of drivers particularly for investment. Panel members from all stakeholder groups – investors, companies, and experts – all recognized that decarbonization support policies, in addition to carbon pricing, are critical to achieve decarbonization. Most panel members agreed that such policies, even if complementary, would have a downwards effect on the carbon price level needed for decarbonizing the power sector.

53 Accessed on Bloomberg Terminal, April 13, 2018.

"To use an internal price for carbon to evaluate assets in investment decisions has been proven to be a sound business practice that clearly protects the long-term interests of the company. It is the board of directors' duty to take care of these interests for a company, therefore boards should defend and even promote the adoption of such a tool. You are not doing your due diligence if you increase the risks of stranded assets for the company you serve as a director."

— **Philippe Joubert,** Chair, The Global Electricity Initiative

In saturated energy markets with constant energy demand, investors identified a need for additional support policies for renewable power generation that provide long-term revenue visibility and facilitate the increasing switch to a low-carbon energy system. However, some panel members from the power sector expect that less saturated energy markets, such as those in emerging countries where demand is outpacing capacity, will require relatively lower carbon prices. The rationale is that as low-carbon intensive generation and storage technologies become increasingly cost competitive, they become the preferred investment choice for new investments, thus reducing the need for high carbon prices. This trend is already beginning to emerge in places such as India.

Capacity remuneration mechanisms and pro-coal, oil, and gas policies were noted as policy factors which would drive up the needed carbon price levels, as they subsidize the old energy infrastructure and hamper the development and integration of new innovative technologies and renewable sources.

It was further noted that the volatility of some factors, such as migration and natural disasters, increase the uncertainty of policy development beyond the 2020-time frame given. Therefore, panel members found it challenging to predict how policy factors will influence the carbon price signal needed.

In more controlled power markets that restrict or prescribe the deployment of certain technologies, policy factors were considered to have less of an effect on the carbon price level needed. Markets where it was considered important, panel members viewed policy factors as increasing the carbon price signal needed to decarbonize by 2050.

Investors highlighted public pressure as an important factor, but with different opinions as to whether it would result in a higher or lower carbon price needed for the power sector to decarbonize.

Panel members mentioned **business and financial** factors the least number of times in their considerations. They were not identified as driving factors for low-carbon investment in the short-run, although some mentioned that they will become more important over time. This could indicate that if carbon price signals lead to favorable economics and market conditions for low-carbon investments, most panel members are confident that such investments could be made.

Some panel members identified a company's portfolio mix of current generation assets as a business factor that affects the carbon price level needed to decarbonize. A company's investment requirements are noted as increasing the carbon price needed. A higher hurdle rate may be deemed necessary due to the perceived additional risk premium given the uncertainty of the future carbon price.

A panel member from the investment community mentioned increased investor interest in lower-carbon climate strategies, as demonstrated by the Task Force on Climate-related Financial Disclosures, as influencing the carbon price level expected in the longer-term.

**Market and economic** factors were considered most frequently by panel members who emphasized the importance of developments in underlying markets as important, if not fundamental, when assessing the effectiveness of price signals.

Nearly all panel members considered the decreasing cost of low-carbon generation technologies as a factor lowering the carbon price level required to drive decarbonization. However, the availability and cost of energy storage and/or demand-side management deployment was emphasized as major hurdle to scaling such technologies and attaining an affordable low-carbon energy system.

Also mentioned was the uncertainty of revenues based on the expected electricity price, demand, and future market share. Wholesale power prices and underlying commodity prices, such as gas and coal, determine marginal prices and command fuel switches. Carbon price effectiveness is therefore dependent on developments of these factors.

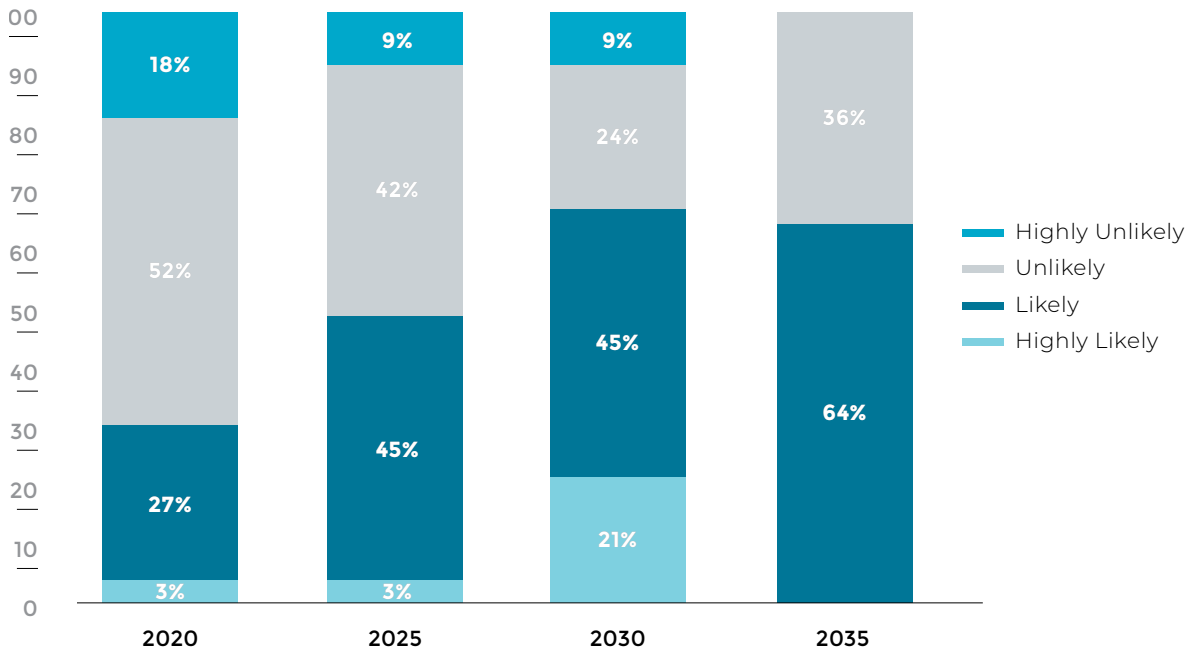
Regarding **technological and infrastructure** factors, most panel members highlighted the availability of renewable resources as priority, followed by the availability of infrastructure for low-carbon technologies. As more renewable capacity is built over time, this could lead to a strain on certain renewable resources such as offshore wind, with suitable areas of deployment running out.

The fear of blackouts was also seen to put pressure on carbon pricing, as the current infrastructure will need to evolve as renewable penetration increases. Should the infrastructure to support low-carbon development become available, this would lower the carbon price needed.

### ARE THESE CARBON PRICES LIKELY?

Panel members were asked to consider the likelihood of their projections materializing as explicit carbon prices in their markets in the 2020, 2025, 2030 and 2035 periods. Figure 12 below summarizes the percentage likelihood of carbon prices materializing based on the total responses in each relevant period.

**Figure 12.** Likelihood of the needed carbon price materializing in the market for the power sector



BOX 4

## Hedging an Uncertain Future: Internal Carbon Prices in the Electric Power Sector[54]

A recently published report from Resources for the Future demonstrates how carbon prices in the US electric power sector are used by companies and electricity regulators to manage policy risk in response to uncertain political climates and changing customer interest. Internal carbon pricing is used in Integrated Resources Planning (IRP) – a public process in which planners work together with utilities to identify and prepare energy options that serve the highest possible public good – to assess future resource portfolios and develop carbon asset retirement plans. The carbon prices are diverse and ranging in average between USD 5-28/metric tCO2e in 2020; USD 5-60/metric tCO2e in 2025; and USD 14-47/metric tCO2e in 2030. This range depends on a variety of underlying factors within IRP, and in particular the potential for future constraints on carbon beyond actual state and federal policies. This is considered crucial in a new, less predictable political environment that is less supportive of climate policy.

In the short-term, the 2020 and 2025-time periods, panelist projections do not anticipate the needed prices to materialize (answering "unlikely" or "highly unlikely") as explicit carbon prices. The trend reverses significantly in the 2030 and 2035 periods in which likely/highly likely sees an increase to 66% and 64% respectively. This indicates panelists expectations of increasing policy mechanisms for external pricing, or the ratcheting up of prices in existing mechanisms.

The longer-term ranges are important for utility, infrastructure and energy companies now given that some of the physical assets in the power sector have a technical lifetime of 40 or more years and CAPEX invested now has an economic lifetime (i.e. the time over which the investment needs to be earned back) of 10 to 15 years. This means that the 2030 and 2035 prices should be taken into consideration now when making CAPEX investment decisions. Taking each country into consideration for these time periods, however, only 3% to 21% of projections needed for decarbonization are considered by panelists as likely or highly likely.

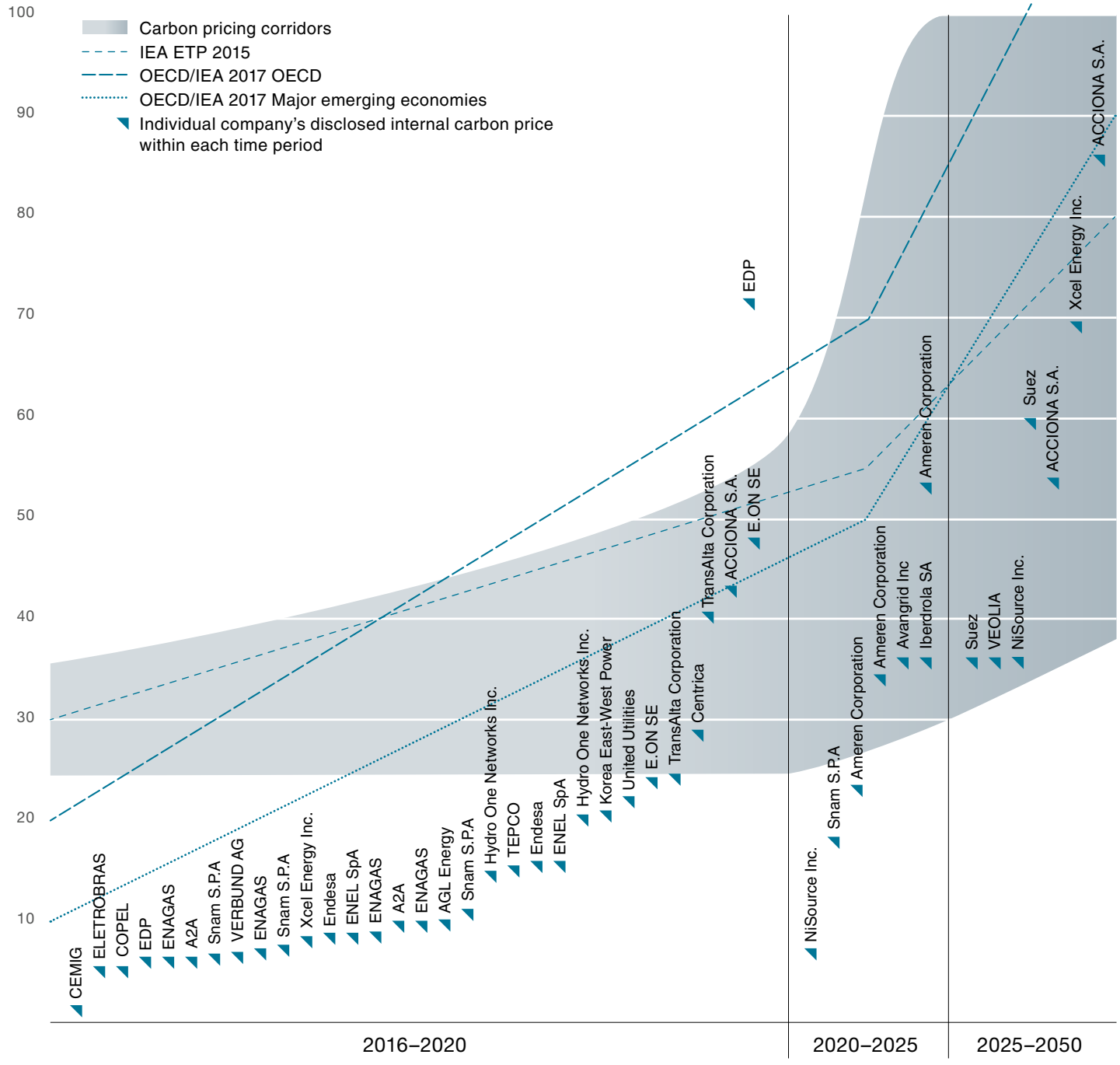
### HOW DO COMPANIES COMPARE TO THE CORRIDOR?

The use of internal carbon pricing, particularly among electric utilities, is already well-established. In 2017, 93 utilities reported their plans or current practice of using an internal carbon price in their capital investment decisions. The average internal carbon price reported among disclosing utilities is USD 35.33/tonne. Proactive companies apply significantly higher carbon prices than current regulation and evaluate investment options against multiple carbon pricing scenarios. The US electric power sector also uses internal carbon pricing in integrated resources planning to assess future resource portfolios and develop carbon asset retirement plans (see box 4).

Figure 13 illustrates the degree to which companies may be failing to plan for the medium- to long-term realities of the cost of carbon. Each red triangle represents an internal carbon price level, associated with a specific time period, that was reported to CDP in 2017 from a company in the utility sector. Many of the physical assets in the power sector have a technical lifetime of 40+ years and CAPEX invested today has ROI of 10 to 15 years. Therefore, it is concerning that only a small number of utility companies disclose their internal carbon pricing assumptions post-2020.

54 Joseph A. Kruger, *Hedging an Uncertain Future: Internal Carbon Prices in the Electric Power Sector*, April 25, 2017.

**Figure 13.** Power sector internal carbon price levels and the Carbon Pricing Corridor




The shaded gray corridor represents the Carbon Pricing Corridor panel members deemed to cover the necessary price levels for 2020-2035 to decarbonize the power sector by 2050 and meet the targets under the Paris Agreement. The red lines represent additional 2°C reference scenarios from the IEA and OECD. Overlapping the reference scenarios and disclosed corporate prices over the Corridor reveals the low-leaning price levels of the utility sector more generally across time periods. For the 2020 period, this gap can be partially explained by the low ambition of current carbon pricing regulations. However, as investors increasingly request stress testing against 2°C scenarios, companies will need to consider the carbon price trajectory forecasted by macroeconomic and industry-developed scenarios.

# 05 THE CARBON PRICING CORRIDORS IN CONTEXT

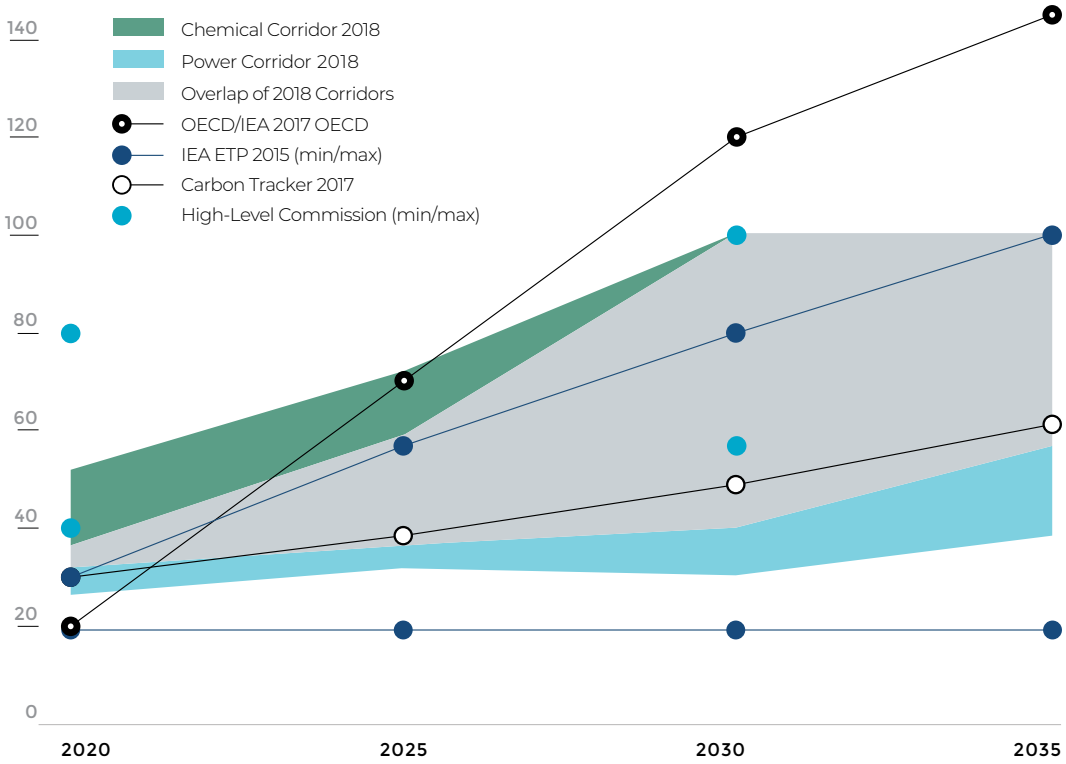
Figure 14 shows the chemical/power sector Corridors resulting from the 2018 inquiry (indicated by the shaded surfaces) compared to four other key studies on carbon price pathways towards a 2°C scenario.[55] The Corridor resulting from the inquiries notably overlaps with most of the other carbon price pathways, though each study includes varying underlying assumptions in their carbon price projections. Compared to the Corridors, the other studies cover different sectors, have varying technology assumptions, and projects varying degrees of emissions reduction ambitions.

The **OECD/IEA 2017** study has the most ambitious scenario with about 95% of global electricity coming from low-carbon sources, including CCS and zero-emission power in several OECD countries and correspondingly high carbon prices.[56] In the **IEA ETP 2015** study the ambition in its 2°C scenario is lower, with 93% of the global electricity coming from low-carbon sources, but the carbon price also covers a variety of sectors apart from the energy sector.[57]

The **Carbon Tracker 2017** pathway has the lowest carbon price projections as these are based on the Nationally Determined Contributions (NDCs) pledged by countries to deliver on the ambitions of the Paris Agreement. However, as Carbon Tracker and other studies point out, the NDCs – and with that the carbon price projections in their study – are insufficient to meet the 2°C limit.[58]

**The High-Level Commission on Carbon Prices,** chaired by renowned economists Joseph Stiglitz and Lord Nicholas Stern, also examined carbon price corridors needed to deliver on the Paris Agreement.[59] The Commission's objective was to identify indicative corridors of carbon prices which can be used to guide the design of carbon pricing instruments and other climate policies, regulations, and measures to incentivize climate action and stimulate innovation that will help deliver on the Paris Agreement. Their report explored explicit carbon pricing options and levels that would induce the necessary change in behaviors, including investment, with policymakers as its main audience.

**Figure 14.** Corridors 2018 inquiry results in comparison with other pathways towards a 2°C scenario




55 IEA, *Energy Technology Perspectives 2017*, 2017.

56 IEA and OECD, *Perspectives for the Energy Transition: Investment needs for a low-carbon ecosystem*, 2017.

57 IEA, *Energy Technology Perspectives 2015*, 2015.

58 Carbon Tracker and Grantham Institute at Imperial College London, *Expect the Unexpected: The disruptive power of low-carbon technology*, February 1, 2017.

59 High-Level Commission on Carbon Prices (World Bank), *Report of the High-Level Commission on Carbon Prices*, 2017.

The Corridors initiative covered in this report is the ideal complement as it is industry-led by market players and seeks to draw links with climate-related financial reporting. With both initiatives working with the Carbon Pricing Leadership Coalition at the World Bank, momentum for carbon pricing gets a boost in both the public and private spheres.

Interestingly, the Commission's carbon price range in the short-run (USD 40-USD 80 in 2020) is much higher than the Corridors produced by the power and chemical sectors, but it eventually converges with the market view of carbon pricing in the longer-term (USD 50-USD 100 in 2030). The short-term discrepancy can be explained in the Commission's own words: "The temperature objective of the Paris Agreement is also achievable with lower near-term carbon prices than indicated above, but doing so would require stronger action through other policies and instruments and/or higher carbon prices later, and may increase the aggregate cost of the transition."

In the short-term, the power sector Corridor is an average USD 8 below that of the chemical sector. However, the high ends of the Corridor ranges converge at USD 100 in 2030-2035. This can partially be explained by the power sector Panel's optimistic views pertaining to the decreasing levelized cost of renewable energy sources.

## LOOKING FORWARD

The Corridors inquiry process surfaced an important distinction between the two sectors. Unlike the clear decarbonization roadmap for the power sector, the diverse and complex nature of the chemical industry makes it challenging to define a decarbonization pathway that applies to all companies within the sector. For example, the International Energy Agency does not provide an emissions reduction pathway for the chemical sector with any level of disaggregation.

This report alone incorporates findings from companies in the commodity, diversified, and specialty chemical sub-sectors – all of which have varying carbon intensities, access to location-based inputs/technologies, and market growth strategies. Technological uncertainties facing some parts of the sector make it challenging for companies and policymakers to identify the investments and mechanisms needed to drive the low-carbon transition.

Given the scale and geographic scope of the transition to decarbonization, the Corridors initiative welcomes opportunities and recommends engaging with others working on carbon pricing from the macroeconomic, industry and investor perspectives. Delivering better information and insight to investors and other stakeholders will contribute to accelerating the shift the world needs to see to stay below 2°C.

# CARBON PRICING LEADERSHIP COALITION

## ADVANCING DIALOGUE ON CARBON PRICING AND CLIMATE RISK

The Carbon Pricing Leadership Coalition (CPLC) brings together leaders across national and sub-national governments, the private sector, and civil society with the goal of putting in place effective carbon pricing policies that maintain competitiveness, create jobs, encourage innovation, and deliver meaningful emissions reductions.

The Coalition aims to drive action through knowledge sharing, targeted technical analysis and public-private dialogues that guide successful carbon pricing policy adoption and accelerate implementation. The CPLC began forming from a groundswell of support for carbon pricing at the 2014 United Nations Climate Summit, where 74 countries and more than 1,000 companies expressed support for carbon pricing. The Coalition now consists of over 150 private sector partners, more than 67 strategic partners, and over 32 governments.

The CPLC engages the private sector to advocate for successful carbon pricing by deepening understanding of the business case for carbon pricing, sharing pathways for expanding carbon pricing as a climate change solution, and encouraging, where appropriate, corporate adoption of internal pricing. The work of the Corridors will be shared with the CPLC network and will help spur dialogue, inform policy design and shape business strategy as companies aim to measure and manage their climate risk – and unlock new investment opportunities. For more information on how to get involved, visit www.carbonpricingleadership.org.

CPLC CARBON PRICING LEADERSHIP COALITION

# APPENDIX

## FACTORS USED IN CORRIDORS INQUIRY

Below is a list of factors that may make it easier or more difficult/costly for the transition to lower emissions in your industry in the future. They may be direct or indirect costs or incentives associated with transitioning to lower emissions (examples here could include fossil fuel subsidies making these fuels cheaper or the lack of available technological solutions, while on the other hand, decarbonization policies such as renewable targets may decrease the costs of raising capital). They could also be factors such as shareholder pressure to decarbonize and the employment costs associated with hiring talent in the fossil-based versus renewable technologies industries.

| | FACTORS | DESCRIPTION |
|---|---|---|
| **1** | **Political and social drivers** | |
| 1a | Presence of other decarbonization support policies | Presence of policies that support the decarbonization of the industry sector on top of the carbon price needed |
| 1b | Presence of indirect decarbonization support policies | Presence of policies that indirectly incentivize the use of low-carbon technologies, e.g. air pollution legislation |
| 1c | Presence of policies counteracting decarbonization | Presence of policies that counteract the carbon price signal or incentivize carbon-intensive generation, e.g. fossil fuel subsidies |
| 1d | Technology deployment restrictions | Legislative restrictions in deploying certain low-carbon technologies, e.g. no CCS allowed or product standards |
| 1e | Public pressure | Presence of public pressure, e.g. divestment campaigns |
| **2** | **Business and financial factors** | |
| 2a | Portfolio mix of current assets | The industrial assets currently in the portfolio and the conditions to meet for writing off the carbon-intensive assets |
| 2b | Company investment requirements | Investment criteria to meet, e.g. payback time, risk premium policy |
| 2c | Internal competition for financial resources | The availability of and access to financial resources, and the requirements for decarbonization investments to top other types of investments |
| 2d | Availability of workforce | The availability of workforce to operate the new assets and willingness to invest in new workforce |
| 2e | Pressure from shareholders | The pressure from shareholders to decarbonize the industrial assets portfolio, e.g. to minimize stranded asset risks |

| | FACTORS | DESCRIPTION |
|---|---|---|
| **3** | **Market and economic factors** | |
| 3a | Uncertainty of the carbon price level | The impact of volatility of the carbon price in the past and expected variations in the future |
| 3b | Uncertainty of revenues | The expected demand for manufactured products and market share in the future |
| 3c | Cost of fossil fuel resources | The expected impact of coal, oil and gas prices on decarbonization investment or deployment decisions |
| 3d | Cost of non-fossil fuel energy resources | The expected impact of prices of biomass fuel and electricity as well as capital costs for renewable energy technologies on decarbonization investment or deployment decisions |
| 3e | Cost of low-carbon technologies | The expected impact of the cost of decarbonization technologies such as fuel switching and CCS on decarbonization investment decisions considering the decreasing cost of technology |
| 3f | Distribution of cost of new technologies over public and private sector | The extent to which governments are willing to take over (some of) the costs related to the development of new technologies |
| **4** | **Technological and infrastructure factors** | |
| 4a | Possibility for new technologies and processes in existing assets | The possibility for existing assets or presence of infrastructure to employ new technologies |
| 4b | Availability of infrastructure for low-carbon technologies | The expected availability of infrastructure to employ low-carbon technology, e.g. CO2 pipelines for CCS or the re-use of alternative feedstocks |
| 4c | Availability of new low-carbon technologies | The expected availability of new and cheaper low-carbon technologies through technological breakthroughs and other innovations such as novel steel smelting processes |
| 4d | Availability of renewable resources | The expected availability of renewable resources to enable low-carbon electrification, e.g. sun, wind, biomass, hydro |

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